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THE PHASE RULE AND CONCEPTIONS OF IGNEOUS MAGMAS—THEIR BEARING ON ORE-DEPOSITION.

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INTRODUCTION.

In the many classifications of ore-deposits which have from time to time appeared, two great divisions have always been clearly defined: the *syngenetic* group, embracing deposits formed at the same time as the enclosing rocks, and the *epigenetic,* embracing those formed long subsequent to their consolidation. Titaniferous magnetite and certain nickel-bearing pyrrhotites have generally been considered as among those ores belonging to the first or syngenetic group and are ascribed to the segregation of the more basic constituents of a molten rock magma by the process of differentiation. By differentiation is understood the separation of the magma while in a still molten state into portions of varying chemical composition. Certain very basic portions have thus become solidified as ores.

Recently much discussion has taken place concerning the epigenetic group. By far the greater number of such deposits are conceded by all writers to have been formed through the medium of circulating waters.

The origin of such waters has, however, of late become the subject of much controversy and two sharply contrasted hypotheses have been formulated and upheld.

Some geologists hold strongly the opinion that waters of meteoric origin, falling on the earth's surface as rain and seeping downward into fractures in the rocks are to be considered as the

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sole agents through which ores have become concentrated into masses sufficiently large for profitable mining. Other students of the subject have, however, recently directed attention to the presence of water and dissolved vapors in igneous rocks and have supposed that these, escaping from the molten magma before its complete consolidation have been the most potent factor in the production of ores.

To the latter class of waters the term *juvenile* has been given—seemingly to emphasize their first appearance at the earth's surface. They are youthful in the sense that they are for the first time to participate in the general meteoric circulation.

In the discussions which have appeared on the origin of these magmatic waters as well as in those dealing with the formation of some ores by magmatic differentiation, it has seemed to the writer that too little attention has been paid to the laws which govern the differentiation of molten magmas, and the emission from them of occluded vapors and too much attention to the work which has been performed by such vapors after their escape from the magma to which they owe their origin.

To the end that some of the points concerning these laws and the bearing which they have on the formation of ores may be more clearly understood the writer ventures to present some considerations relating to rock magmas which do not yet seem to have received the emphasis which they deserve.

THE PHASE RULE.

Since some of the terms that are used in this paper may not be familiar to all readers a few definitions are here introduced.

A chemical system is a collection of chemical substances so situated that they may react on each other free from any outside interference except that due to variations of temperature, pressure and degree of concentration of the substances. The substances which go to make up the system are known as its components, and may be one or more. If the system has the same chemical and physical composition throughout it is said to be homogeneous. If there are distinct and mechanically separable portions which are homogeneous in themselves these are termed

phases and the system is said to be heterogeneous. For example, a solution of sodium chloride in water would be a homogeneous system consisting of two components and one phase. Ice and water, on the other hand, would be a heterogeneous system of one component and two phases. It was stated that the only outside influences to be allowed to act on the system were variations in temperature, pressure and degree of concentration of the components. These are known as the *variable parameters* and in the following discussion only the first two will be employed. When there is no tendency to a reaction between the parts of a system, *i. e.*, when the relative amount of the phases is not changing, the system is said to be in equilibrium. When there is such a tendency, but the reaction or change is prevented by resistances, such as lack of molecular freedom for example, the system is said to be metastable.

Gibbs' phase rule states that in any chemical system in equilibrium the number of phases present may not exceed the sum of the number of components plus the number of variable parameters. When such is the case equilibrium only exists for that particular combination of parameters, and the system is non-variant. If any parameter varies equilibrium will be destroyed. Where the number of phases present is one less than the sum of the components and parameters equilibrium can exist for a series of combinations of parameters which is given by the equation $x = f(y)$, x and y being the two parameters which are variable. The system is then said to be mono-variant. Where the number of phases is two less than the sum of the components and parameters equilibrium is retained over a considerable range of variation of the parameters and the system is said to be di-variant. These are best understood by examining the equilibrium curve for the one component system H_2O.

A is the only point of equilibrium for the three phases, ice, water and vapor, and is found at a pressure of 4.6 mm. of mercury and .0076° C. For the combinations of pressure and temperature found along the line *AC*, water and vapor can exist together in equilibrium; similarly, ice and water along *AD* and ice and vapor along *AB*. That is to say, starting with water and

vapor in equilibrium at the temperature and pressure defined by the point *A*, the pressure may be varied and equilibrium will be retained, providing the temperature also is varied so that the locus of temperature and pressure is a point on the line *AC*. Where only one phase is present, as in the areas *BAC*, *CAD* and

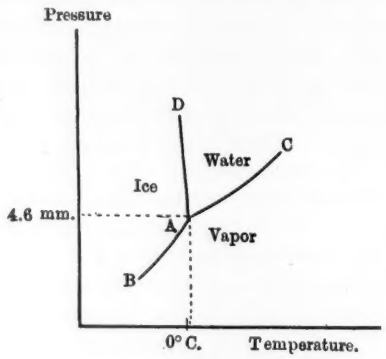


FIG. 1.

DAB, both temperature and pressure may vary over considerable ranges without destroying the equilibrium.

This brief preliminary statement will suffice to clear the ground for further discussion. A full treatment is found in the works on the phase-rule by Findlay and by Bancroft and also in many of the later text-books on physical chemistry.

APPLICATION OF THE RULE TO IGNEOUS MAGMAS.

LeChatelier in 1900 applied the phase rule to the case of a hypothetical granite containing only SiO_2, Al_2O_3 and K_2O, in which quartz, orthoclase and muscovite were the phases. But beyond simple statements by several authors that the phase rule can probably be applied to rocks no further attention has been given to the subject. It is, however, one that promises to become eventually of greatest importance to the petrographer, because it cannot be doubted that this law governs the conditions of equilibrium in igneous magmas and rocks.

An igneous rock in all its stages from complete fluidity to complete solidification is a chemical system. Findlay gives this rule for determining the number of components in a system: "As the components there are to be chosen the smallest number of independently variable constituents by means of which each phase participating in the state of equilibrium can be expressed in the form of a chemical equation." In choosing these, to simplify the discussion, let us omit all reference to such components as TiO_2, P_2O_5, Zr_2O, S, etc., for when they are present we always find their corresponding phases, titanite or sphene, apatite, zircon, pyrite, etc. Let us also omit all reference to the Fe_2O_3, for where it has not magnetite as its corresponding phase it is mutually replaceable with Al_2O_3 and can be considered with it as one component.

We then see that the elementary oxides of an igneous rock fall into four component-groups: SiO_2, Al_2O_3, (Ca, Mg, Fe)O, (K_2, Na_2)O. Then, in accord with the phase rule, we should have not more than four phases present in a rock which is in stable equilibrium. Let us see how this accords with the facts and for this purpose let us consider the igneous rocks described in Bulletin 150[1] of the United States Geological Survey, for the double reason that the mineralogical and chemical composition are there accurately given and are available for convenient reference.

No. 59. Rhyolitic pumice.
Four phases: glass, feldspar, pyroxene, biotite. Stable.

No. 60. Rhyolitic obsidian.
Four phases: glass, biotite, augite, feldspar. Stable.

No. 61. Rhyolitic pearlite.
Four phases: glass, quartz, feldspar, augite. Stable.

No. 63. Liparite.
Four phases: quartz, feldspar, biotite, garnet. Stable.

No. 64. Nevadite.
Four phases: quartz, feldspar, biotite, glass. Stable.

But contrast with the above the following:

[1] J. S. Diller, "Educational Series of Rock Specimens." Bull. 150, U. S. Geol. Surv.

No. 81. Dacite.
Six phases: biotite, hornblende, pyroxene, feldspar, quartz, glass; the lack of equilibrium is evidenced by the partial devitrification of the glass. Unstable.

No. 82. Dacite.
Six phases: hornblende, biotite, feldspar, pyroxene, quartz, glass. Unstable.

No. 80. Dacite.
Five phases: glass, feldspar, hypersthene, hornblende, quartz.

It should be noted here that while the presence of a phase of glass may in general be taken to indicate unstable equilibrium, since when it is present the transformations which have taken place are necessarily irreversible; yet the oxides locked up in the glass would generally have given rise to some further phase than those already present. It could rarely happen that the glass would have such a composition as to yield only a further quantity of those minerals already present. The glass cannot be looked upon as an undifferentiated eutectic, therefore, but only as evidence of incompleted transformations.

Again:

No. 68. Hornblende-biotite granite.
Four phases: quartz, biotite, hornblende, feldspar. Stable.

No. 69. Biotite-hornblende granite.
Four phases: feldspar, quartz, hornblende, biotite. Stable.

No. 66. Granite.
Three phases: quartz, feldspar, biotite. Stable.

No. 67. Granite.
Three phases: feldspar, quartz, biotite. Stable.

No. 70. Trachyte.
Three phases: feldspar, quartz, biotite. Stable.

No. 71. Syenite.
Three phases: feldspar, amphibole, biotite. Stable.

No. 73. Phonolite.
Three phases: nepheline, sanidine, ægirine. Stable.

The fact that the various feldspars are considered as a single phase, while pyroxene and amphibole are considered separately, may be called in question. That this is proper is seen when we reflect that (CaO, MgO, FeO) is a true component-group, while (K_2O, Na_2O) is most frequently not so. By so regarding it and taking no account of the differences in the feldspars the double error produces no effect beyond simplifying the discussion.

The five examples last given show a feature which deserves emphasis, namely, that the phase rule simply imposes a maximum in regard to the number of phases which may be present. If the original composition of the rock magma happened to be just right there is no reason why it should not yield only one phase. That this may sometimes happen is shown in the case of dunite, where, neglecting the chromite, there is only one phase present. We might mention also certain anorthosites. It is also instanced by the following:

No. 106. Diabase.
Two phases: augite, feldspar.

No. 110. Pyroxenite.
Two phases: diallage, enstatite.

No. 114. Saxonite.
Two phases: olivine, enstatite.

In many of these cases it may be found by careful examination with this rule in mind that some one further phase is present, though in very small amount. This need not be true, however, as has just been pointed out.

Without stopping to describe them in detail let us now note that Nos. 75, 77, 83, 84, 85, 86, 89, 90, 93, 105 and 108 have four phases present, Nos. 87, 91, 102 and 107 have three. Nos. 74 and 101 have five, and are evidently in unstable equilibrium. No. 76 has six phases and No. 92 has five, but in both of these analcite is present and we have therefore another component, H_2O.

It should be said in all fairness that it seems unquestionable that a strict application of the phase rule to these complex systems cannot be made so simple as the treatment here given. For

a strict application many factors remain yet to be determined and it has seemed justifiable to discuss the question in a preliminary paper that might serve to bring it to the minds of those in petrographic work in order that its solution may be hastened.

It will be granted that according to the above evidence the phase rule may be employed to determine whether any given rock is in stable or unstable equilibrium in the condition in which we find it. That a rock may be in unstable equilibrium (*i. e.*, that the minerals which we find present in it may not be those which such a chemical system should yield under the condition under which it now exists) has not apparently been emphasized heretofore by petrographers in general. We find on one hand Rosenbusch, who urged that magmas similar in chemical composition must give rise to similar mineral aggregates, and on the other, Roth and many more, who have brought evidence to show that this is not always the case. That the differences observed may be due to the possibility that the rocks in question may not have attained the phase constitution (or mineral constitution) requisite for equilibrium in their present condition has not apparently been considered, although the statement that the conditions under which the two rocks solidified must have been different is a distinct step in this direction. In discussing this question many references will be made to conditions and resulting structures met with in the binary alloys, for it can be easily seen that it is by the aid of our knowledge of these rather simple two-component systems that the more complicated systems met with in the rocks can best be explained.

It has been recently shown by Vogt[1] that mixtures of augite and olivine form a eutectiferous series, with the eutectic at 70 per cent. augite. Day[2] and Allen have also shown that albite and anorthite form a series of isomorphous mixtures. In view of these positive results it can scarcely be doubted that the mineral aggregates of rock and the metallic mineral aggregates of alloys differ from each other only in degree, and not in kind. It is not beyond reason, therefore, to assume that in many instances

[1] *Vermlands. Berg. Annalen*, p. 82 (1904).
[2] *Amer. Jour. Sci.*, 19: 93 (1905).

the problems met with in the igneous rocks can be solved in the same manner as similar problems in the metallic alloys.

In the case of the alloys of copper and tin it is found that between 8 per cent. and 75 per cent. Cu the fused "magma" on cooling at first yields crystals of Cu_3Sn, which freeze out of it. At a lower temperature the mother-liquor reacts with these crystals, forming CuSn. This change is not complete, however, for the CuSn formed coats the crystals of Cu_3Sn, thus protecting them from further attack. After solidification is complete we have present Cu_3Sn, CuSn and the excess-metal. This, of course, gives unstable equilibrium, but the production of unstable equilibrium can only be avoided by taking special precautions to effect complete reaction between the CuSn and the mother-liquor.

In the case of the quartz-basalts, we find that the magma on cooling first yielded crystals of quartz. At a lower temperature the mother-liquor has reacted with these, forming a shell of augite around them, thus preventing further action on the part of the mother-liquor. That this is the case is further evidenced by the fact that we do not find a similar mineral aggregate in the granitic textured rocks of similar chemical composition. In these latter the slow cooling has allowed the reaction to become completed. The reaction in the case of some of the copper-tin alloys can scarcely become completed, even under the most favorable circumstances, since the change takes place in the solid state where freedom of movement is necessarily limited. The great probability of change in the solid in the case of certain soda-leucites which break down into orthoclase and nephelite, yielding the pseudo-leucites, has been pointed out by the author in conjunction with Mr. C. W. Knight in a paper shortly to appear.

According to the laws of chance with four components it could rarely happen that the magma could have such a composition initially as to yield only two phases; but it is obvious that this two-phase occurrence is rather common, especially among the basic rocks. This might come from one or both of two causes. The first may be a tendency of the molten magma to yield two such minerals as to come out as nearly even as possible. This is a supposition for which it would be difficult indeed to find proof.

The second cause may be a tendency of the molten magma, while standing at high temperature at great depths, to separate into two or more partial magmas that individually would yield a more simple mineral composition.

The latter is a question that has occupied the attention of petrographers since the earliest days of the history of petrography. A great volume of literature has been written on this subject without, apparently, drawing very near to its solution. The literature to the end of 1891 has been ably summarized by J. P. Iddings,[1] and since that date it has been added to by Becker,[2] Michel-Levy,[3] Brögger[4] and many others. Suffice it here to say that on the one hand we have many students of the occurrences in the field who are convinced by their study of these that segregation of magmas does occur, and have therefore devised hypotheses to explain it. Naturally the hypothesis derived to explain a given occurrence has usually appeared very unsatisfactory to those who have devised a different hypothesis to explain another set of phenomena. And on the other hand we have those who, arguing from the standpoint of physics and chemistry, have found that all the various hypotheses advanced by the workers are faulty in many particulars. This new contribution to the already bulky literature can only be excused on the ground that it considers the question from a new standpoint: that of the essential similarity between igneous rocks and metallic alloys, in each case considered as chemical systems.

In order to fix clearly in mind the conditions which we are discussing let us assume a mass of magma situated at *P*, far enough beneath the earth's crust to be considerably above the temperature at which it would fuse under atmospheric pressure, the fusion being prevented by the pressure to which it is subjected. For simplicity let us assume that it is perfectly homogeneous, a solid solution. Its location on the equilibrium curve,—regarding for the moment the solution as a one-component sys-

[1] *Bull. Phil. Soc. Wash.*, XII: 89 (1892).
[2] *Amer. Jour. Sci.*, 3: 21 (1897).
[3] *Bull. Geol. Soc. d. France*, 24: 326 (1897).
[4] "Gangefolge des Laurdalits" (1898).

tem,—is shown at M in Fig. 2, it being at pressure B and temperature A.

This is not in any sense a liquid; the fact that it is at a temperature that at a less pressure would cause fusion does not make it any more a liquid than would its being at a pressure that at a higher temperature would cause fusion. Some increase of molecular freedom may indeed be a result of this high temperature, but not to the extent found in a liquid.

Suppose that by orogenic movements the pressure at P is re-

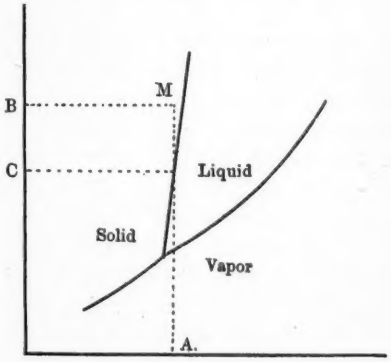


FIG. 2.

lieved until it falls below C. Then the magma would immediately liquefy. As is seen from Fig. 2, the liquefaction will be accompanied by an increase in volume and if no space is gained for expansion this will quickly increase the pressure to greater than C again and liquefaction will cease. If, however, fissures have penetrated to P, then these offer ample space for expansion; the liquefied magma will force itself up into these and if the pressure is sufficiently great to force it to the surface considerable amounts may be poured out. This can not continue indefinitely, however, since the fusing magma is abstracting considerable quantities of heat at P as latent heat of fusion much faster than it can diffuse inwards from the surrounding masses. Necessarily, then, the temperature at P will soon be reduced to below that

necessary for fusion, and liquefaction, with its consequent expansion and extrusion of molten magma, will cease. Meanwhile, heat is steadily diffusing inward from the surrounding area and will in the course of a longer or shorter period bring the temperature at *P* back to nearly or quite what it was at first. Extrusion of molten material cannot immediately follow, however, for the fissure will be now plugged with partially or wholly solidified magma. The pressure due to expansion may build up until this resistance is overcome, perhaps with an explosive eruption. Or it may be necessary to wait until earth movements again open up a passage.

The magma which is extruded is subjected to somewhat different conditions from that which remains behind. Let us consider them separately, beginning with the latter.

A large volume of evidence is generalized by Iddings in the statement that the magma first extruded is median in composition and is followed by more basic and more acid varieties. The material first extruded has the average composition at *P*. At the moment of the cessation of the extrusion of magma we have a considerable body at *B* which is liquid and only slightly above its melting point. That it is liquid is seen in a moment when we reflect that the last material to fuse, and therefore to abstract the heat which reduced the temperature to below the fusing point, was on the border. The border, then, is the coolest part. As the heat diffuses inward from the surrounding area it is obvious that the increased pressure would not cause solidification of the molten material,—only further liquefaction would cease.

The condition of affairs at *P* is now quite different from before. The material is now liquid and will probably remain so over a long period of time, for, except by loss of heat or increase of pressure, it cannot solidify. Apparently from the evidence already brought forward by many observers, but notably Brögger and Iddings, this liquid, which we have so far been regarding as a homogeneous liquid, breaks up into at least two conjugate solutions. A good example of such action is seen in the case of chloroform, water and acetic acid, of which a mixture at 20° C. yields these two conjugate solutions.

	Chloroform.	Acetic Acid.	Water.
Lighter layer	15.11%	50.18%	34.71%
Heavier layer	70.14%	25.75%	4.12%

Doubtless the separation into two such layers would be very slow, due to the comparative viscosity of the liquid. It should not be prohibitively slow, however, for Roberts-Austen has shown that such rigid materials as lead and gold will diffuse into each other where in contact, and it must be remembered that the viscosity of a lava after being poured out on the surface and having suffered almost total loss of the vapors which are present at the time at which we are considering it, is scarcely a safe index of the viscosity of the mass in question.

Calling the lighter layer *A* and the heavier layer *B*, after the lapse of some time such a state as that in Fig. 3 might exist.

According to the degree of molecular freedom existing in the magma this segregation will proceed more or less rapidly until it may become almost complete. The separation may be interrupted from time to time by eruptions which may pour forth magma of progressively different compositions, perhaps also somewhat remixing that which remains behind. A complete separation may or may not take place before the final extrusion, according to circumstances. In case the later orogenic movements should open another fissure which intersects the reservoir at a lower point we may have the same reservoir yielding two different kinds of material at the same time. In case all the material were extruded through the same vent, the last would naturally be the most basic, since that would be the heavier layer.

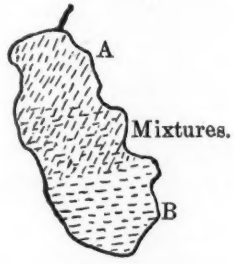


FIG. 3.

In regard to the detailed mechanism of this separation and the composition of the two layers in particular cases, we are not in the possession of sufficient information to venture any exact statements. On the face of it it would appear that the ultimate composition of the lighter layer would probably correspond to some-

thing like a pegmatite and the heavier a pyroxenite or other ultrabasic type. The difference between these and the final products actually attained would be a measure of the completeness of the separation. It must not be forgotten that the original composition of the material at P would condition the composition of the final products as well.

We must notice in regard to the foregoing that the partial magmas to be theoretically obtained from any given mixture would vary with the temperature and pressure at which they separated. Since the partial magmas finally obtained in a given case depend on the initial composition, the pressure and temperature, the degree of molecular freedom, the length of time during which separation has been going on, and various rather indefinite factors, such as mixture during eruption, etc., it is plain that a great variety of products should be expected that would exhibit no apparent conformity to law. If the exact influence of all these factors were known the conformity would doubtless be seen to be complete.

So far it has been assumed that the layers remained completely liquid until the time of extrusion. This may not be the case in many instances. The freezing out of certain minerals will introduce other factors. One of these we may denominate the progression of the eutectic. It has already been noted that in the copper-tin series Cu_3Sn first freezes out and the system progresses toward a eutectic composed of Cu_3Sn and Cu or Sn, as the case may be. At a somewhat lower temperature the mother-liquor reacts with the Cu_3Sn, partially destroying it, and the system then progresses toward a eutectic composed of CuSn and the excess of either metal. The essential similarity of the structures thus produced and those observed in the quartz-basalts has been remarked. We might mention further the structures figured on pp. 606 and 612 of the Twelfth Annual Report of the United States Geological Survey, as observed by J. P. Iddings in the eruptives of Electric Peak and of Sepulchre Mountain, and those seen in the phenomenon of resorption in general. In all such cases the rock is very metastable, yielding readily to thermal or other metamorphism and often varying widely from

point to point. It would seem that metastability is a somewhat common phenomenon in igneous rocks.

The separation of solid phases also requires a brief consideration. While the liquid magma is homogeneous we have only one phase present. In case it separates into two conjugate solutions then the number of phases is two. Further variations of the parameters may cause the separation of solid phases, where the variation is slow, the total number of phases cannot exceed the number of components, as is evident. That these solid phases should not become concentrated at the top or bottom, according to their specific gravity, could only result from the action of the force of gravity being opposed by some resistance sufficiently great to prevent the concentration. This would be the rigidity of the medium through which the minerals had to move. That the viscosity of a magma is sufficiently great to prevent the motion of solid particles through it has been urged by several authors, most recently by Pirsson.[1] The same author states, however, that convection currents must have been important factors in differentiation. When we remember that the action of convection currents depends upon slight differences in specific gravity in the liquid, induced by differences in temperature, the incompatibility of the latter statement with the former is striking. It is hard to understand how convection currents could operate or exist in any liquid that was viscous to a noteworthy degree. It is probably true that solid phases do not, speaking generally, separate out from differences in specific gravity, yet with heavy minerals that freeze out at high temperatures, such as magnetite, it is to be expected that such a separation might frequently take place, since at the higher temperatures the viscosity is greatly lowered. But that a low degree of viscosity is necessary to permit molecular flow is not to be taken for granted, since molecular flow takes place in the solid in many alloys. The hardening of amalgams is partly due to this cause, and Day and Allen[2] have recently ascribed the sintering of powdered glasses at temperatures much below their fusing points to this as well. Conditions which would prevent the motion of solid particles through

[1] Bull. 237, U. S. G. S., p. 185.
[2] *Amer. Jour. Sci.*, 19: 93 (1905).

a magma cannot then be regarded as prohibitive of molecular flow. How extensive are the movements of material which molecular flow can bring about is a question which cannot yet be answered.

In considering the material poured out on the surface in our hypothetical case, we note that it is especially in these rapidly chilled rocks that metastability is observed. This is evident from a glance at the table previously given; indeed it is to be expected, for the solidification of a granitic rock must have been so slow as to generally permit the attainment of equilibrium. A very good example of extreme metastability in surface rocks is seen in the eruptives of Electric Peak and Sepulchre Mountain, to which reference has already been made. But it must not be assumed that all granitic rocks are necessarily in stable equilibrium in the strict physical-chemical sense, for changes which should have taken place in the mineral constitution may have been resisted by the passive resistance of lack of molecular freedom after the first solidification. Leucite, for example, always exhibits an apparent tendency to break down, and where it is in a soda rock, may actually do so, yielding pseudo-leucites of orthoclase and nephelite. Uralitization may be a similar phenomenon.

But with a *strict* definition of stability, that the changes which have taken place are reversible, not even the granites can be regarded as being stable, for vapors that were an essential part of the system have escaped, and these must be brought back before the changes of the system can be reversed. In other words, an igneous rock is only a portion of the original system. This fact does not invalidate the previous discussion, since the return of the vapor phases would introduce a corresponding number of components; but exemplifies what was stated earlier, that a complete and accurate discussion of this subject requires information that is not at present in our possession.

A feature of intrusives especially that deserves mention is the frequent occurrence of a progressive change in mineral constitution as we proceed inward from the contact. Usually we find an increasing proportion of the acid minerals, but in some cases

the reverse is true. This is not a remarkable phenomenon, but is indeed what we should expect. For since the walls are the coolest part of the intrusive mass, the first crystals to freeze out have their inception there. Most minerals exhibit a tendency to set up as few centers of crystallization as possible; this is evidenced by the usual coarseness of the phenocrysts found even in the rapidly chilled rocks. Therefore the material in the central portion would tend to migrate toward the sides and solidify upon the centers already established there rather than set up new ones. It would necessarily follow that the first minerals to freeze would be concentrated at the border and the last at the center. Usually the basic minerals freeze first, but in certain cases, diabases and quartz basalts, for example, the acidic minerals are the first to solidify.

BEARING ON ORE DEPOSITION.

Not the least important result of these observations is the consideration that the escaping liquid and vapor phases produced during the solidification and cooling of a magma are most potent factors in the production of ore deposits. During the freezing out of the minerals the former naturally remain dissolved in the mother-liquor and there is much evidence to show the persistence of mother-liquor to temperatures and pressures remarkably low compared with those ordinarily considered to exist in depth. When released, as they must be, at different depths and at pressures and temperatures such as to be comparable perhaps to those in a modern high-pressure steam boiler, escaping to the surface they seep through rock masses, traverse interstitial channels, follow lines of weakness or open fissures. Diverse in initial character and content, subjected to the action of widely differing wall rocks in their upward course, they naturally produce a variety of phenomena: simple deposition here, selective action there, metasomatic replacement elsewhere. Vein fillings of widely different character are thus to be expected. Perhaps it is not too much to hope that some day the exact processes and actions of such solutions may be determined with the same exactitude as has been done for salt deposits by the truly admirable work of Van't Hoff and his pupils.

Since the foregoing was written, Miers,[1] in his vice-presidential address to the British Association for the Advancement of Science, while speaking along similar lines, has offered a most valuable suggestion from his own work in regard to the labile state and its bearing on the formation of phenocrysts. The point brought forward is that cooling salt solutions, on reaching the saturation point, do not usually crystallize immediately, despite the excess of dissolved solid, but over a certain range below this point can only crystallize when solid particles of the same salt (or one isomorphous with it) are brought into the solution, or, in the phraseology of Dr. Miers, the solution is *inoculated*. Beyond this range, which is called the labile state, centers of crystallization are set up spontaneously and crystallization of the excess of solid proceeds automatically. The explanation suggested seems most reasonable, except for the difficulty of explaining the initial inoculation of the magma. That this could take place from the borders, as suggested, is quite impossible and it seems much more probable that the slow rate of freezing out of the phenocrysts and the strong tendency to form as few centers of crystallization as possible is the true explanation. It must not be forgotten that the actions in a solution cooling at the rate of degrees in minutes can not justly be supposed identical with those of a solution cooling at the rate of degrees in years.

The writer must acknowledge his indebtedness to Professor J. F. Kemp for his interest and encouragement in the preparation of the foregoing paper.

[1] *Nature*, 72: 405 (1905).

STRUCTURAL FEATURES OF THE JOPLIN DISTRICT.[1]

C. E. SIEBENTHAL.

INTRODUCTION.

From the beginning of geologic investigation in the Joplin district there has been much difference of opinion in regard to the structural features. All are agreed that the region, in common with the remainder of the Mississippi Valley, was subject to extensive erosion before the deposition of the Coal Measures. All are agreed that while minor faulting is common, horizontal juxtaposition of Coal Measures and Mississippian rocks can only be accepted as evidence of profound faulting with much hesitation. Nevertheless, this position of the rocks, taken with the shape of the shale bodies, the brecciation and the slickensiding, has led some to affirm vertical displacements of 150 feet or more. Adherence to the theory of a deep-seated origin for the ore-bearing solutions has perhaps influenced this interpretation of the evidence, for in general those who hold to the theory of lateral secretion of the ores have been inclined to regard the faulting as slight in amount.

PREVIOUS WORK.

The first geologist to study the Joplin district closely was Schmidt[2] who makes no mention of faulting, but considers that solution of the underlying limestones and the contraction due to dolomization were competent to cause the stratigraphic disturbances.

Jenney[3] firmly believed that the ores were deposited from

[1] Published by permission of the director of the United States Geological Survey.

[2] The Lead and Zinc Region of Southwest Missouri, by Adolph Schmidt and Alexander Leonhard. Geol. Surv. Mo., vol. 1, 1873-4, p. 381, *et seq.*

[3] "The Lead and Zinc Deposits of the Mississippi Valley," by Walter P. Jenney. *Trans. A. I. M. E.*, Vol. XXII., 1894, pp. 171–225, read at Chicago meeting, 1893.

solutions derived from the crystallines through fissures of "indefinite extension in depth." Though he nowhere notes individual faults of more than three or four feet, he speaks of step-fault zones with an aggregate throw of 100 feet, and suggests that faults which are more clearly defined below, split up into numerous branching fracture planes at the surface. It is inconceivable that faults of three or four feet should extend downward through more than 2,000 feet to the crystallines, and from this fact as well as the way in which he refers to the chert "reef," it seems that he thought faulting of the magnitude of 100 feet displacement was not uncommon.

Blake,[1] though a believer in the lateral secretion of the ore, in discussing Jenney's paper, affirms that extensive faulting exists in the district, and cites the stratigraphic relations on the Oswego tract near Joplin as an example.

Nason,[2] likewise discussing Jenney's paper, points out that the specular iron ores of the central Ozark country are deposited in limestone caverns and sinks, and that in one of them not more than 20 miles from the central crystalline area there were found Lower Carboniferous fossils, thus linking together the iron and the lead and zinc deposits both in point of time and mode of occurrence. The iron ores being shown to be derived by lateral secretion and descending waters, it is suggested that the lead and zinc ores were also derived that way. The brecciation and disturbance of the rocks associated with the iron deposits are accounted for by the caving in of solution chambers in the limestone.

Winslow,[3] after exhaustive investigation, concludes that the stratigraphic breaks are the results of depositional unconformity of the Coal Measures, the irregular surface of the Mississippian being due to erosion channels and solution cavities or "sinks." The local disturbances of the strata, the brecciation and the slickensiding he regards as incidents in the progressive development of a subterranean drainage system. He conceives the ore

[1] *Trans. A. I. M. E.*, Vol. XXII., pp. 621–634.
[2] *Trans. A. I. M. E.*, Vol. XXII., p. 636.
[3] "Lead and Zinc," by Arthur Winslow. Geol. Surv. Mo., Vol. VII., 1894. pp. 421, 430.

deposits as arising by lateral secretion and enriched by residual concentration.

Robertson,[1] working with Winslow, is in complete accord with the expressed results of Winslow's investigation.

Haworth[2] conceives that the elevation of the Ozark dome, flat on top and monoclinal around the margin, caused a stretching of the strata in the border area which resulted in a series of fissures, tangential to the margin of the uplift, narrowing and pinching out with moderate depth, and in general without vertical displacement. In the coal fields adjacent to the Joplin area these fissures, which, filled with clay, become "horsebacks," are quite plentiful, from three to five feet or in exceptional cases as much as thirty or forty feet in width, and a mile or more in length. They die out in number and intensity with greater distance from the margin of the uplift. The ore-filled openings in limestone and cherts, which about Galena and Joplin become so numerous as to constitute "ribbed ground," are analogous in origin, though the production of fissures in the brittle cherts has resulted in great brecciation.

Bain[3] describes and maps numerous faults with throws of 100 or 150 feet. Some of these are described as double, letting down into the Lower Carboniferous rocks narrow bands of the Coal Measures from 40 to 100 feet wide. In other cases the fault-plane is marked by a zone twenty feet in thickness of broken and disturbed shale and chert. In general, he assumes that zones of brecciation denote fault-planes. The ore solutions under artesian pressure in the Cambro-Silurian below, ascended in these fault fissures through the Devono-Carboniferous shale and being precipitated in the Lower Carboniferous limestones and cherts at the surface, have since been variously enriched or impoverished by descending and laterally moving waters.

[1] "The Missouri Lead and Zinc Deosits," by James D. Robertson. *Am. Geol.*, Vol. XV., 1895, pp. 235–248.

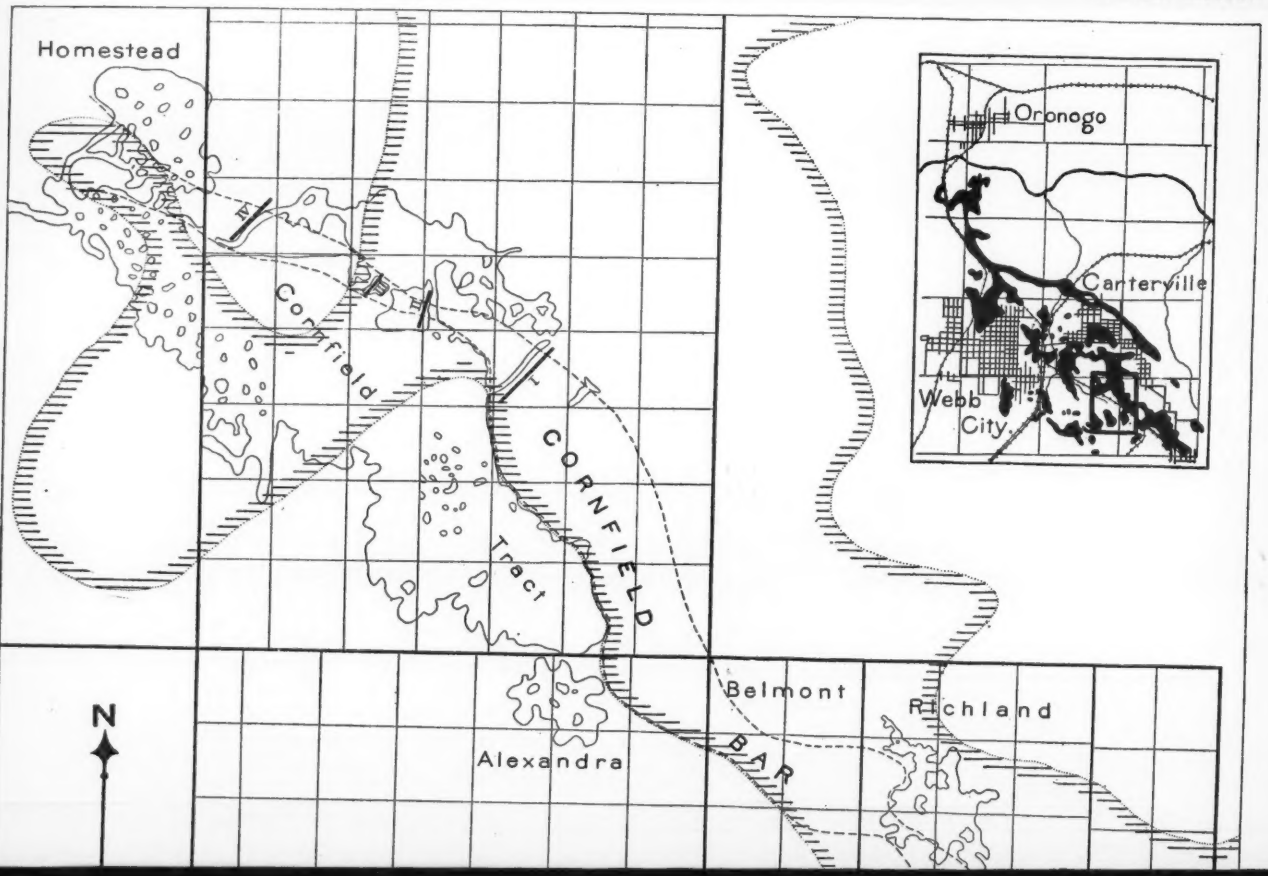
[2] "Relations Between the Ozark Uplift and Ore Deposits," by Erasmus Haworth. *Bull. G. S. A.*, Vol. II., pp. 231–240.

[3] Preliminary Report on the Lead and Zinc Deposits of the Ozark Region, by Bain, H. F., Van Hise, C. R., and Adams, G. I. U. S. Geol. Surv., Twenty-second Ann. Rept., Pt. III., pp. 23–227, 1901.

THE CORNFIELD REGION.

The question of the magnitude of the faulting is one of much scientific interest and economic importance, and different investigators have been greatly influenced in their theories of the origin of the ore deposits by their estimates of the amount of throw. In the course of areal and stratigraphic mapping of the district for the U. S. Geological Survey under the direction of Dr. W. S. Tangier Smith, the writer visited the blanket-vein or "sheet-ground" workings on the Cornfield tract of the American, Zinc, Lead and Smelting Company, and neighboring tracts south of Carterville. Through this territory runs a line of disturbance that throws much light on the structural features of the district.

In this vicinity there are irregular patches of Coal Measure shales and sandstones lying unconformably in depressions in the Boone formation which constitutes the country rock of the region. The sheet-ground is reached about 170 feet from the surface and the working face averages about ten feet in height. The ore occurs near the top of a heavy development of flint in the Boone, the superjacent rocks consisting of the limestones and cherts of the Boone, together with patches of Coal-Measure shale and sandstone as noted. Here and there the undisturbed stratigraphic arrangement or "regular formation" is replaced by "confused" or "broken ground," an intimate mixture of limestone and chert bowlders in a cement of spar (dolomite), selvage or shale, or all three. The confused ground, where ore-bearing is referred to as the "upper" or soft ground in contradistinction to the sheet-ground which is the "lower" or hard ground. The upper ground may extend downwards as far as the more insoluble chert member which thus becomes the "bed rock," the two "grounds" being separated by a ledge of barren chert, or the upper ground may cut into or through the sheet-ground, though this is infrequent. Any abrupt change of ground along a horizontal plane is called a "bar," provided it is not ore-bearing. This "bar" may be the wall rock of limestone, chert, shale or sandstone, or it may be a band of either of these between two reaches of confused or broken ground, in which case it may be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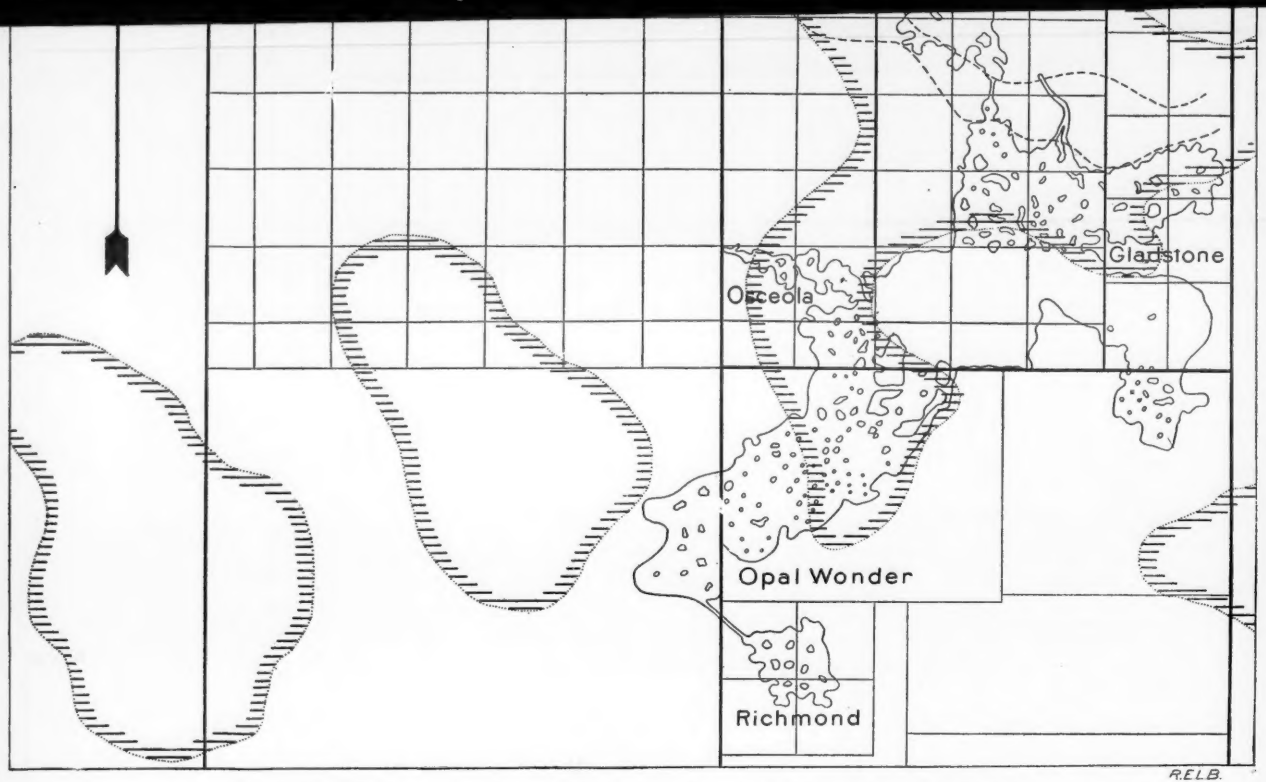

MAP OF PORTION OF JASPER COUNTY, MISSOURI, SHOWING LOCATION OF CORNFIELD BAR AND SECTIONS.

Black area on small map = Coal Measure Shales. Shaded areas on large map = Coal Measure Shales. Solid light lines = outlines of underground workings. Dotted light lines = the Cornfield Bar. Rectangles on small key map = square miles.

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called a "rib." Again the bar may be a belt of confused ground interrupting the regular formation as in the case about to be described.

THE CORNFIELD "BAR."

On the Cornfield and adjoining properties the sheet-ground has been mined out over an area 2,000 feet long by 400 to 800 feet wide, thus offering excellent opportunity to detect any deformation of the bedding. Through this area runs a "barren bar" of deformed, confused and broken ground, in width varying from 50 to 300 feet, and in length, with its extension beyond the Cornfield, nearly three-quarters of a mile. The relation of the surface outcrops of the shale to the bar can be seen on the accompanying map. The deformation is most strongly marked near the western end of the bar, and its structure is clearly exposed in a half dozen cross drifts through it.

As one approaches the bar from either side the first manifestation is a slight dip of the rocks towards it. Next long cracks in the roof make their appearance parallel to the face of the bar, the dip increases, the fractures come at closer intervals and hade in opposite direction to the dip, the inclination being in inverse proportion to the steepness of the dip, until the chert has a sheeted structure. At this point the mining usually stops because of lean ore and the bad roof. Beyond, the dip may be reversed and the rocks resume their normal position as sheet-ground, or the trough of the bar may be occupied by a confused mass of limestone and chert bowlders mixed with mud or masses of contorted shale. The bar is usually barren or poor in ore, but the richest of the sheet-ground lies within 30 or 40 feet of it.

An instance where the trough of the bar is occupied by contorted shale is seen in section I. At the south end of the drift the chert dips increasingly toward the bar, and the roof overhead is fractured parallel to it. Thirty feet in from the mouth of the drift the bedded chert is replaced by confused ground consisting of broken shale and chert bowlders. The middle of the bar consists of contorted and broken shale, having the form of a closely appressed syncline, with here and there chunks of coal. The shale has caved away for some distance above the roof of the

drift, and the débris below conceals a portion of the section, but it is evident from the recurving of the shale that it does not extend below the floor of the drift. Beyond the shale, the formations succeed in reverse order until the level sheet-ground is reached. About 50 feet beyond the shale there is a small normal fault with a throw of about 18 inches.

About 300 feet northwestward from the preceding section a north and south cross drift gives section II. Here the trough of the bar is synclinal, the upper ledge of chert in the sheet-ground being depressed just to the bottom of the drift. At the north end of the drift the rocks are fractured in the usual fashion, but at the south end the dip is steeper and there is a small normal fault with a displacement of about two feet, the downthrow being to the south, compensated, however, by a slight rise in the strata and an abrupt upward bend bringing the strata up to the sheet-ground level.

Two hundred feet farther west the syncline is even more gentle as indicated in cross section III. where the greatest depression is not more than two or three feet. The center of the trough exhibits a number of vertical fractures which disturb more or less the regularity of the stratification. Near the south end of the section a wide crevice dipping 20°–25° to the south is filled with finely crushed white chert.

Three hundred feet northwest of the last section a long narrow drift starting at a shaft near the west line of the Cornfield tract cuts angling northeastward across the bar and exposes section IV. In all that part of the drift near the southern edge of the bar the chert is so broken and sheeted by the almost vertical fractures as to seem to stand on edge. A little farther towards the middle of the bar the dip of the fractures gets lower and lower and the strata begin to dip toward the bar. Steeply dipping cherts and limestones inclined toward each other occur near the center of the bar and are separated from the bedded cherts on either side by a space occupied by brecciated, confused rocks. At the middle of the bar overlying the inclined cherts and limestones is a mass of red clay with scattering limestones and chert bowlders. This is very soft ground and in one place a mud pocket has caved high in the roof.

Between sections III. and IV., a small room cut in the north face of the bar shows a reverse distributive fault with throws of two, three and four inches respectively, the downthrow being to the south.

Farther west on the Homestead ground in the cross drifts 100 feet west of the line the strata are so badly fractured as to be nearly indistinguishable, though there seems to be not more than a few feet depression. On the north edge of the bar about 200 feet west of the line there is a small distributive reverse fault with a total throw of four feet, the downthrow being to the south. At the westernmost cross drift on the Homestead, the chert dips 1°–2° to the south on the north side of the bar and 4° north on the south side of the bar. There are very few fractures and the bedding is not disturbed, though there are occasional thin sheets of mud between the chert ledges, which is in general an evidence of some disturbance.

A drift at the 210-foot level, 25 feet below the sheet-ground, starts in where the three drifts intersect at the north edge of the Homestead workings and runs eastward with the bar, when, veering to the south, it leaves the bar. The same disturbance of the rocks is reported to exist in this lower drift as is noticed at the sheet-ground level,

On the Alexandra ground adjoining the Cornfield on the south, the same conditions obtain. The ground is mined up to the edge of the bar where the vertical fractures set in and the chert dips 14° under the bar. A slight displacement is noticeable along one of the fractures, resulting in a reverse fault with a downthrow of four inches to the northeast. The fault-plane is a crevice one inch wide filled with finely shattered chert. A hole in the roof of the drift northeast from the mill shows shale and flint bowlders and indicates that the characteristic broken ground here reaches down to the sheet-ground.

On the Belmont ground near the north side of the bar there is a reverse fault of two feet, the downthrow being to the southwest. Along the fault is a crevice an inch in width filled with finely shattered chert. A sheet of ore is sharply cut off and dragged down a little along the fault-plane.

On the Richland ground the bar is marked by a barren or "dead" rib, fractures and dips being noted in but one place near the western edge of the tract. The top of the sheet-ground here is about 160 feet from the surface and the characteristic broken ground comes down to within three or four feet of the sheet-ground throughout the mine, both being worked together in places, and resulting in rooms 60 to 80 feet high. Between the sheet-ground and the broken ground is usually a heavy ledge of white flint. Above this, shale is found in the cracks of the flint, then more shale with flat chert bowlders, then more and more shale with irregular bowlders until it becomes the usual mixed ground, the shale making up a third of the mass. In places this mixed ground reaches down into the sheet-ground and forms a caving spot in the roof. There are dead ribs in the broken ground although they do not coincide with those in the sheet-ground. The dead ribs in the sheet-ground are not noticeably different from the rest of the ground except for the lack of ore and "deader" appearance of the flint, and occasional rare thin shale and mud sheets between the flint strata.

East of the Richland the bar extends as a barren stretch but without deformation features so far as developed.

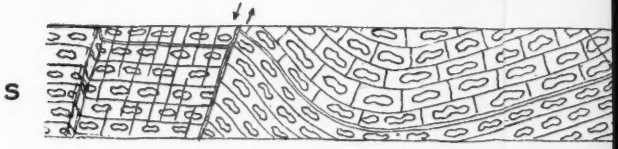
DISCUSSION.

After noting the surface distribution of the shale, a study of section I. would very logically lead one to conclude that the shale was thrown down here 185 feet from the surface as the result of a fault or perhaps more probably of a double fault letting down a long narrow block of shale. This conclusion would be strengthened by the knowledge that a shaft 150 feet to the southeast and also in the bar went through 110 feet of shale. The evidence is as decisive for deep faulting as has been seen in the district. Had the sheet-ground not been worked this interpretation could not have been successfully controverted. As it is, however, a study of the next section to the west 150 feet, shows that the total displacement by faulting and folding is only ten feet. On the Richland, on the continuation of the bar to the southeast 1400 feet, there is no deformation whatever, though

PLATE III.

Section I

Section II



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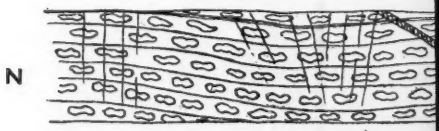
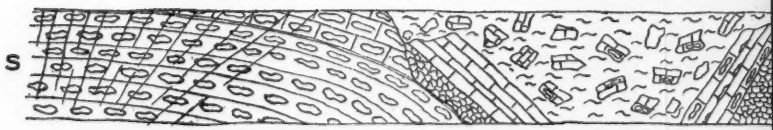


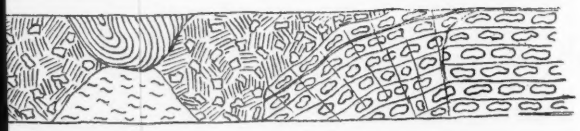
Section IV



CROSS-SECTIONS OF CORNFIELD BAR, JOPLIN DISTRICT, JASP

Vertical Scale, 1 inch = 15 feet. Horizontal Scale, 1 inc

ection I



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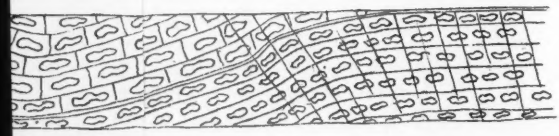

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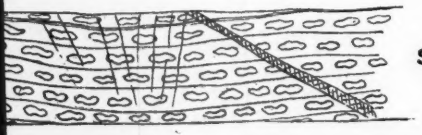

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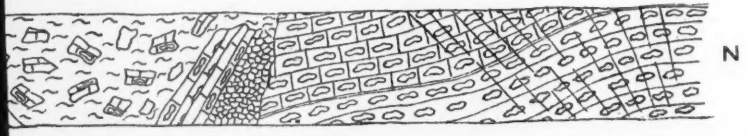


ELD BAR, JOPLIN DISTRICT, JASPER COUNTY, MISSOURI.
nch = 15 feet. Horizontal Scale, 1 inch = 50 feet.

the shale reaches down 150 feet. On the Alexandra the shale shows in the roof of a drift 175 feet below the surface over an undisturbed part of the sheet-ground. The low position of the shale then is, *per se,* not evidence in the least that it was faulted there. It seems natural to conclude that the displacement is but little more in section I. than in section II., not over 20 or 25 feet, and probably not so much. Section III. displays very little deformation, but section IV. again shows disturbance which might be interpreted as extensive faulting, although the absence of shale would minimize the estimates of magnitude. On the Homestead, on the other hand, the faulting dies out again altogether, and the last cross drift to the west shows only an unbroken flexure with a depression of eight or ten feet in the middle.

If the shale was not faulted down, how came it there? In all probability, judging by the evidence at hand from this and other occurrences in the district, three factors took part in throwing the shale to such depths. First and most important is the non-conformity of the shale and limestone. In the middle of the branching shale patch which extends northward through the Cornfield tract to Carterville, the shale reaches various depths from 50 to 100 feet and more. At one point about 200 feet north of the bar the solid shale is 50 feet in depth and below that to 170 feet there is reported the usual mixed shale and bowlders. And we have seen how, on the Richland, the shale reaches down to the upper limit of the sheet-ground with the sheet-ground itself entirely undisturbed. The unconformity alone therefore is sufficient to account for the presence of the shale at these depths.

The second important factor has been solution. In places where the roofs of caverns have given away letting down the rocks above, they often assume a synclinal shape, strongly suggestive of the attitude of the steeply dipping limestones and cherts in section IV. The contorted shale in section I. would hardly take the shape it has as a result of simple faulting, but would quite naturally do so if it had sunk down from above into a cavity. In other places in the district the shale fills extensive cave galleries in such a way that it could only have been deposited

by underground drainage. Specific illustration of this case is to be found in the thin sheets of mud and shale between the ledges of flint in the sheet-ground and in the holes in the roof of the sheet-ground where the broken ground makes its appearance as seen on the Alexandra and Richland tracts.

Lastly, faulting and deformation are plainly shown in the sections. The faulting is both normal and reverse. It does not exceed 25 or 30 feet at the utmost and is incompetent except in combination with the unconformity to bring the shale to such depths.

CONCLUSION.

Summing up the evidence over the district in general, of which the illustration given is typical, we reach the conclusion that the region has had a history somewhat as follows:

I. Pre-Coal Measure elevation into land with resulting torsion cracks, determining the direction of subterranean drainage, followed, with one interruption, by extensive erosion and development also of an underground drainage system.

II. Subsidence, Coal Measure deposition, elevation and post Carboniferous deformation, with further development of underground drainage.

During the subsidence the erosion channels, sink-holes and cave galleries of the preceding period were filled up. These channels, surface and subterranean, were lines of weakness and under the stress of later deformation yielded to the pressure and were reversely faulted, while the district at large was thrown into wide gentle folds, the larger ones of which have a height of 100 feet or more. Further solution allowed more settling into the old caverns and resulted in normal faults and in further brecciation and slickensliding along the side walls. The deposition of the ore post-dates the deposition of the shale, but antedates some of the faulting as shown in cases noted in the sheet-ground where the ore has been displaced by faults. Such faults may, however, be due to readjustment of solution cavities, and may be of quite recent date.

[NOTE. A discussion of this paper by Mr. H. Foster Bain will be found under the head of "Discussion," page 172. Ed.]

ORE-HORIZONS IN THE VEINS OF THE SAN JUAN MOUNTAINS, COLORADO.

CHESTER WELLS PURINGTON.

The fact that the ore of metalliferous veins occurs in shoots is well known. Such shoots may vary greatly in dimensions, but generally have their longer diameters more nearly approaching the vertical than the horizontal. In the great majority of cases, in fact, where shoots of ore occur in veins whose origin is due to the filling of previously formed open fissures, the shoots have a definite oblique pitch in the plane of the vein, such pitch being entirely independent of the dip of the vein in which they occur.

The phenomena of pitching shoots of ore are characteristic not only of veins in slates, schists and gneisses whose laminae correspond in direction with the strike of the veins contained in them, but occur sometimes with extraoradinary regularity in veins of ore which penetrate rocks of entirely homogeneous texture.

In the consideration of the features attendant on secondary enrichment of ore-bodies, it has been recognized that layers of bonanza ore occur, independent of the tendency of the rich portions of the ore as originally deposited to form in definite shoots. Such layers may be nearly horizontal in extent, but there is rarely more than one rich layer, which lies at a moderate vertical distance below the outcrop. Further, there are well-known cases in which the character of the ore changes successively in depth, several layers or horizons of ore in descending containing a greater or less quantity of a given sulphide. In these cases, however, the change may be independent of the value of the ore.

In the present paper it is the intention of the writer to consider an occurrence in the eroded plateau region of southwest Colorado known as the San Juan Mountains, where nearly vertical or steeply dipping metalliferous veins traverse several thou-

sands of feet of nearly horizontally bedded lavas and underlying sediments. Cañons of from three to six thousand feet in depth have been cut in the plateau below its original level, affording excellent sections for the study of the vein phenomena, and good facilities for the exploitation of the gold, silver and lead values which the veins contain.

In the part of this region known as the Telluride district, and comprising the drainage of the head-streams of the San Miguel river especially, the rock formations, although exceedingly regular in physical form are of great heterogeneity of composition. The average height of the mountain crests is 13,000 feet, and the upper 300 to 600 feet of the section is occupied by a fairly homogeneous rhyolitic flow, known as the Potosi[1] rhyolite. Succeeding this in descending order comes a section of 500 feet of a dense blue andesite. Underlying this is a brecciated andesitic tuff about 200 feet in thickness, the bulk of the fragments in which are of rhyolite. The blue andesite and rhyolitic basal breccia are known as the Silverton series.

Beneath this is a thickness of 2,000 feet of andesitic flow-breccias, volcanic ash-beds, with a few intercalated layers of pure andesite and some beds which are so full of rounded pebbles of granite and older sedimentaries as to more properly be called conglomerate. Boulders up to six and seven feet in diameter occur in some of the conglomeratic layers. To this immense thickness Mr. Cross has given the name of the San Juan breccias.

Underlying the breccias and bedded entirely conformably with them is a 200- to 300-foot thickness of heavy conglomerate in which the pebbles are all rounded. Beneath the conglomerate are sandstones of Triassic age, reddish color, unconformable with the overlying rocks, but still not varying over 15 degrees from the horizontal in dip. Few of the cañons in the vicinity of the known ore-bodies and working mines are cut below the level of these sandstones, and about Telluride no mining exploration has penetrated to their base.

It is with the volcanic lavas and breccias that the Telluride

[1] The names adopted are those given by Mr. Whitman Cross, whose classic work in the San Juan region is too well known to need farther reference.

miner concerns himself, since in the red sandstones below the ore, so far as known, is of little or no value.

Fissures of great length, in some cases of five miles, and of a vertical extent exceeding five thousand feet, cut, all the rocks enumerated arranged in definite system, to which I have elsewhere referred. Many of these fissures when formed afforded open space, which has subsequently been filled with ore and gangue minerals. In consequence the region is one traversed by metalliferous veins, the exploitation of some of which has proved handsomely remunerative.

In the working out of the ore-bodies it has been found that the ore lies in layers or "floors." Although secondary enrichment, especially of the silver values, has undoubtedly played some part, yet it is evident in the stoping up of a section on one of the veins that several alternations of rich and poor layers of ore occur.

The first and most evident cause of this is purely mechanical. Fissuring did not take place with facility in all the rocks. In the Potosi or upper rhyolite, veins which attain a width of from five to fifteen feet in the Silverton andesite, are represented by seams of quartz scarcely one-half inch in width, or by zones of such seams, not exceeding two feet in aggregate width. As the Silverton series of andesite is fairly homogeneous in texture down to the top of the rhyolitic layer, the veins penetrating it have more nearly uniform width in it, and do not pinch again until they enter the rhyolitic breccia at the base. The rhyolitic layer at the base of the Silverton series is from 150 to 300 feet thick, and occurs at an average elevation of 11,900 feet. In Savage, Marshall, Middle, Ingram and Bridal Veil basins it has resisted erosion so that it forms an elevated floor or pavement for the upper portions of these basins or glacial cirques.

It matters little how large the veins may be above this thin layer of rhyolitic material or below; in traversing the layer they generally pinch to narrow seams, and occasionally are represented by fissures carrying no quartz. Bare ledges of rock, nearly flat in surface, and in which every minute fracture can be plainly seen, frequently occur, covering some acres of ground in the

path of the big veins. It is rare, however, that anything more than a one-half inch stringer or narrow belt of inch stringers may be seen. For example, the Tomboy vein, in Savage Basin, which appears as a vein of several feet in width both above and below the rhyolitic horizon, is represented as it crosses the flat at 12,000 feet elevation in this basin by surface outcrops of a narrow fissured zone, in some places carrying less than three inches of quartz. A remarkable case occurs in this basin on the Occidental claim, where a short drift is run on a quartz vein three feet in width at the horizon of 12,100 feet in the pure andesite of the Silverton series. At a vertical distance less than 100 feet below, and less than 500 feet away, a bare ledge of the rhyolitic layer outcrops directly on the strike of the vein, and only two fissures carrying one-quarter of an inch of width of quartz each represent the vein on its strike.

Below the Silverton series, in the 2,000 feet of San Juan breccias, the veins have generally good but variable width. The writer has noted that where the contained pebbles and fragments of the breccias are of granite or of material harder than the enclosing volcanic matrix the original fissures formed with great difficulty, and resulting veins are in consequence narrow and locally diverted from their strike. On the other hand, when the fragments are of andesitic character, the fractures cut through the matrix and fragments alike with sharpness and no diversion.

Widenings of the veins to ten and even fifteen feet with solid quartz filling between walls are not uncommon in the breccias.

In the underlying conglomerate the fissuring took place with difficulty. They are generally narrow and irregular, and the veins have rarely any importance.

In the red sandstones, the veins which may be large in the breccias generally pinch to one- or two-inch quartz seams, or narrow belts of such seams. If a limestone layer intervenes, the veins are likely to widen in such a layer. In the mines lying in the sediments below Ouray remarkable cases of such alternating width of vein-material are seen in successive layers of sandstone and limestone. In these cases, however, the effect of fissuring is obscured by that of molecular replacement.

The second cause of the occurrence of horizontal ore horizons in the Telluride district is one less easily understood, and is, in the opinion of the writer, dependent on the varying influence of the successive horizons of wall-rock in the precipitation of the metals in the veins.

In rhyolitic layers, even where veins are of workable size, quartz and gangue minerals (rhodonite, calcite, rhodochrosite, etc.) occur, and even lead sulphide, as in certain cases about Silverton, but values in gold and silver are notably lacking. In the Silverton pure andesite, however, a rock considerably lower in silica contents, the ore is generally good, frequently of high grade, as for example in the Camp Bird, Tomboy, Smuggler-Union and Humboldt mines.

In the San Juan andesitic breccias the value of the ore is said by mine managers to vary in value from layer to layer. Such variations may be observed within the limits of a stope, in working up on the vein. The writer has noticed that at the horizon of 11,000 feet, and for 300 feet vertically above, many of the large ore-bodies in the San Juan breccias occur. A single stope in the Smuggler-Union vein within these vertical limits exceeds one mile in length. In this part of the section the breccias are of rather basic character and contain comparatively few fragments.

It appears probable that the ore-horizons of the San Juan, judging from the occurrences about Telluride, are dependent on two causes, the one mechanical, the other chemical. As regards the fissuring, the rule of narrow veins in the rhyolitic layers will be found to hold, although it is not without exceptions. The principle that richer layers or floors of ore occur coincident with less siliceous rather than more siliceous layers of wall-rock is one which the writer believes can be established.

THE GEOLOGY OF THE DIAMOND AND CARBONADO WASHINGS OF BAHIA, BRAZIL.

ORVILLE A. DERBY.[1]

[Translated by J. C. Branner.]

A trip to the diamond washings of Brazil recently made by the writer afforded an opportunity for obtaining a general idea of the geologic structure of the basin of Rio Paraguassú, which in its upper part includes the principal diamond region of the state of Bahia—the so-called "Chapada Diamantina," or diamond plateau.

The Paraguassú river crosses four regions different from one another in their geologic make-up and in their topographic and economic features. The first of these regions includes the entire district about the headwaters of the river and its principal tributary, the Santo Antonio, and extends as far as the falls of Passagem de Andarahy; the second extends from this point to the village of Bebedouro, about seventy kilometers by the wagon road below Passagem and twenty kilometers above the terminal station on the railway at Bandeira de Mello; the third extends from Bebedouro to the city of Maragogipe with a width of about three

[1] Professor O. A. Derby, for many years State Geologist of São Paulo, Brazil, was lately employed by the State of Bahia to report upon the geology of the part of the state from which the carbonados are derived. The present paper is translated from the report made to the Governor and published in the Portuguese language in the *Diario da Bahia* of June 1 and June 3, 1905. It is the most important paper thus far published upon the geology of the carbonados. It does not deal with the origin of the diamonds and carbonados, for the deposits mentioned are clearly secondary, but the geologic structure of the region is of the greatest economic importance in connection with prospective mining. Other papers by Mr. Derby upon diamonds are as follows:

1. "Geology of the Diamond," *Am. Jour. Sci.*, XXIII., 97–99, 1882.
2. "Modes of Occurrence of the Diamond in Brazil," *Am. Jour. Sci.*, XXIV., 34–42, 1882.
3. "The Genesis of the Diamond," *Science*, IX., 57–58, 1887.
4. "Brazilian Evidence on the Genesis of the Diamond," *Jour. Geol.*, VI., 121–146. Chicago, 1898.

hundred kilometers, and the fourth from the last named point to the mouth of the river with a width of only a few kilometers.

The first region is composed essentially of heavy beds of hard yellowish sandstone which often pass into a conglomerate. These beds, of which the thickness is estimated at more than five hundred meters, are profoundly disturbed, being thrown into folds that may be compared to the waves of the sea, and are also cut by faults with the uplift sides forming enormous steep-faced cliffs. It is therefore essentially a mountainous region of the Appalachian type.

The general elevation of the region is about 1,000 meters; some peaks and ranges rise from two hundred to five hundred meters above this level, while the deeper valleys are cut some seven hundred meters below it.

On account of the hardness of the rocks and of the disturbances (folds and faults) they have undergone, the topography is extremely rough and the vegetation sparse, many of the ranges being almost bare of soil and consequently of plant life. Here and there are small areas of gentler topographic outlines where the decomposition of the rocks has furnished a thick soil, and these places are generally covered with a scrubby vegetation or with forests. On account of the sandy nature of the underlying rocks the soil of the region is generally weak and is better adapted to cattle grazing than to agriculture. As for mineral resources the only ones thus far utilized are diamonds and carbonados, and the geologic structure affords but little hope of the existence of other minerals except perhaps where some older series of rocks may happen to crop out.

The second region is made up partly of beds of yellowish sandstone rather similar in appearance to those of the first region, but for the most part softer, more clayey and containing interbedded strata of limestone some tens of meters in thickness.

The thickness of this series seems to be from two hundred to three hundred meters, and the beds are approximately horizontal, though there have probably been some vertical displacements by means of faults.

On account of its geologic constitution the region is relatively

flat and has a general elevation of from five hundred to six hundred meters. It is cut, however, by the valleys of the Paraguassú and its tributary, the river Una, which are some two hundred and more meters below the general level.

The decomposition of the rocks is much more pronounced in this than in the first region, so that it is only on the steepest slopes that the character of the underlying rocks can be seen.

The limestone when concealed, as it generally is, often discloses its presence by the flinty segregations which clutter the roadways at places where they have been set free by the decomposition of the enclosing rock.

The soil cap over the region is generally quite thick, and supports forests which at many places are dense. Where the limestone comes to the surface the soil is of a dark red color and of a tallowy consistency. This soil is preferred by the few planters of the region in spite of its being deficient in running water, which, as is usual in limestone regions, sinks through the fractures and caverns that abound in the rock.

The falls of the Paraguassú river formed by the rocks of this region yield diamonds and carbonados which are obtained by diving, but it is uncertain whether these stones are derived from the rocks belonging to this region or are brought down from the region above.

Nothing is known of any other minerals of economic importance with the exception of the limestone which has been used at many places for the making of lime.

It seems that the sandstone and limestone formation which characterizes a zone of some tens of kilometers in width along the eastern base of the Serra das Lavras, extends toward the north and makes up a large part of the so-called Matto do Urobo and also toward the south in the limestone region of Brejo Grande. From an agricultural point of view this zone is probably the most promising of the central interior of the State of Bahia.

The third region is made up of gneissic rocks abundantly cut by plutonic eruptions apparently of the granitic type. Its lowest portions are between 200 and 300 meters above sea level. In view of its geologic constitution the extent of the relatively

horizontal surface features along the river and railway is rather striking. Above the comparatively low and flat base rise hills and peaks to an elevation of 800 meters and more. The low parts along the railway are covered with characteristic vegetation called "satinga," but it seems that the more elevated portions are covered by forests and have the reputation of being fertile. The rapid passage of the writer through this zone upon the railway did not permit observations upon its agricultural capabilities or mineral resources, but at several places it was possible to note that the soil is thin even in flat places where a greater thickness was to have been expected, and that many of the granite hills were almost completely barren of vegetation. So far as can be judged from its geologic constitution it is to be expected that there are in places deposits of manganese, iron, graphite and perhaps other minerals of economic value.

The fourth region is made up of beds of the soft sandstone of Cretaceous and Tertiary ages that characterize the Reconcavo regions of Bahia and offers but little of interest in the present study.

The diamonds (including in this term the carbonados which rarely if ever fail to accompany the true diamonds in the Bahia Chapada) are especially characteristic of the first region while their sporadic occurrence in the second and third regions may plausibly be attributed to ancient or recent transportation from the first. In all the localities examined (Santa Isabel, Chique-Chique, Andarahy, Lenções and Palmeiras) their occurrence is intimately associated with a thick bed of conglomerate which is near the middle of the sandstone formation above described. This conglomerate represents a deposit of pebbles formed at a remote geologic epoch in the same way that pebbles are formed at the present time, and the same as the incoherent conglomerates not yet turned into hard rock in which the miners look for diamonds. At many places it is evident that a portion of the gravels worked by the miners is simply the conglomerate decomposed in situ without having undergone any recent transportation or rearrangement.

There is thus repeated in this region the phenomenon already

observed in the State of Minas Geraes where there are several important washings in decomposed conglomerate and where as in Grão Mogol, diamonds have been found embedded in the hard conglomerate.

The recent and unconsolidated gravels naturally contain a mixture of the elementary materials derived from all the rocks observed in the neighborhood, but where they are richest it is evident that the greater part of these materials come from the conglomerate or " pedra cravada " as the miners call it, which seldom fails to outcrop in immediate contact or in close proximity to the most productive washings. It is thus evident that the great, if not the only repository of diamonds in the region is the conglomerate or gravel fossilized and interbedded with the great sandstone series that characterizes the Serra das Lavras.

The heaviest bed of conglomerate exposes an average thickness of from six to ten meters, but it contains at many places thin beds of fine grained sandstone. As has been said, its position is near the middle of the great sandstone series, so that in general terms there are about 250 meters of sandstone above it and as much more below it. There are many waterworn pebbles scattered through the sandstone that overlies the conglomerate, as well as thin intercalated beds of genuine conglomerate, and these features give a conglomeratic character to all of the formation from the middle upward. It is not, however, characteristic of the lower sandstone, and together with other circumstances leads to the belief that a geologic division should be made at the base of the conglomerate, and that the lower beds belong to an independent and older division than that above. It is also a striking fact that many of the pebbles and rolled blocks embedded in the conglomerate are identical with the rocks of the underlying beds.

The conglomerate offers a greater resistance to atmospheric influence than the beds associated with it, and for this reason it produces most of the escarpments and makes the topography extremely rough and picturesque.

The sandstone beds above the conglomerate are especially subject to weathering and are at many places trenched by valleys

in whose walls are exposed large surfaces of naked conglomerate. Thus along almost all the eastern base of the mountains in the region between Santa Isabel and Lençōes over a distance of more than sixty kilometers, the conglomerate covers almost the entire slope of the mountain like tiles on a slanting roof, and plunges with a dip of from 20 to 30 degrees toward the east, into the bottom of the valleys of the Piabas, Chique-Chique, Andarahy and S. José rivers that skirt the mountains through this region, while the opposite sides of the valleys are formed principally by beds of the upper sandstone.

On account of the folding of the series the beds are several times repeated along a line normal to the general orientation of the mountain range which is north-south. These folds may be easily recognized by the conglomerate outcrops which on an east-west line are exposed at various places dipping now toward the east and now toward the west. Thus for example in the section mentioned between Santa Isabel and Lençōes the dip of the conglomerate is always toward the east and it forms the entire eastern slope of the range, but on passing over the crest of the ridge it reappears with a western dip after an interval in which a great thickness of the beds of the lower sandstone is exposed.

After another break occupied by the beds of the upper sandstone (the conglomerate having passed beneath it) the same rock appears again in the vicinity of Palmares when the diamond washings likewise reappear.

Judging from information gathered from others the same thing happens with the ranges and washings of Chapada Velha, Santo Ignacio and others that form a chain of diamond-bearing ridges extending to near the Rio São Francisco.

If it is true that the conglomerate, or ancient gravel, is the great repository of diamonds and carbonados in the Lavras region it follows that the stock of these minerals still in existence must be enormous. The points of easiest attack thus far worked are insignificant in comparison with the masses of materials containing the precious stones still untouched.

It is evident, however, that only a relatively small part of this mass can be worked with profit by the processes now in

use. It remains to be ascertained whether modern technology, by using the hydraulic power so abundant and so favorably situated in the region, affords a method of operation less expensive than the value of the products.

This question is one to be solved by the mining engineer rather than by the geologist, but it seems to the writer that the probabilities of a favorable solution are strong enough to justify serious studies and experiments.

Outside of the region of the Serra das Lavras properly speaking, which ends on the east in the escarpment covered by the conglomerate extending from Lençõe in the direction of Santa Isabel, the diamond washings on land become rarer or are altogether wanting. At a few points, however, where the bed of Rio Paraguassú and some other places have been worked by diving, the locations are so far from the Serra that it is difficult to believe that the diamonds have been brought from there. The most important of these points is the falls of Funil near Bebedouro and consequently on the eastern margin of the region of sandstone and limestone above described. This fall is formed by a heavy bed of conglomerate quite like that of the diamond region, but which, it seems, must belong to another geologic horizon superior to that of the Serra. Its cobble-stones are principally of granitic rocks and the conglomerate rests directly upon rocks of this kind. It seems probable that the diamonds found at this place come from the local conglomerate or from some of the rocks associated with it, but upon this point nothing could be conclusively determined.

As the geologic series of this second zone is more recent than that of the Serra and hence presumably formed in part of materials derived from it, there is a strong presumption that it is also here and there diamond-bearing. The "formation" or concentrated washings of these gravels taken from below the falls at Funil are quite different from those of Lavras in the greater abundance of granitic elements, presumably owing to the fact that streams flow in above from granitic and gneissic regions.

As to the geologic horizon to which the two (or three) series of rocks above indicated should be referred, nothing decisive

was observed. Search for fossils that might have thrown light on this question was fruitless. For various reasons that will not be mentioned here, the writer judges them to be older than the secondary rocks to which are referred the diamond deposits of South Africa, and those of the region of Bagagem in Minas Geraes, and that they will eventually be found to belong to the middle or upper part of the paleozoic.

The diamond region of Salobro in the municipality of Cannavieiras is especially interesting for it differs notably from the other diamond bearing regions of Brazil on account of its proximity to the sea (about 60 kilometers) and on account of the absence of marked topographic relief that is generally associated with the occurrence of the diamond. The region is moderately hilly with an elevation of a little more than a hundred meters, while the highest serras to be seen on the horizon have no apparent relation with the occurrence of diamonds in Rio Salobro. The entire region is covered by a thick soil that supports heavy forests which conceal the rocks and render geologic observations difficult.

On the banks and at the falls of Rio Pardo hardly six kilometers from the Salobro washings it was ascertained that the underlying rocks of the region consist of a series of beds of sandstone and argillaceous shales with a heavy bed of conglomerate made up of rolled blocks of different kinds of granitic and gneissic rocks. This series appears to have a thickness of several hundred meters and has a strong eastward dip.

In the beds of Rio Salobro and of its small tributaries this conglomerate is exposed at several places and the washings thus far opened are all in the immediate vicinity of its outcrops. In order to verify the hypothesis of the conglomerate origin of the diamonds, Mr. Pedro Benazet kindly had washed separately about one and a half cubic meters of decomposed conglomerate selected by the writer for the purpose. The result was a diamond weighing three grains. It thus seems to be beyond doubt that here in the litoral zone as well as at Lavras, the diamond is directly associated with the conglomerate which thus furnishes for prospecting a valuable guide, easily found and recognized.

It is evident that a formation as thick as that exposed on the rivers Pardo and Salobro must have a wide distribution in this zone, and there is a strong probability that at many if not at all points where it crops out, it contains diamonds as it does on the Salobro. Furthermore, this last district still affords a very large field for mining operations.

THE GOLD DEPOSITS OF PLOMO, SAN LUIS PARK, COLORADO.

CHARLES GODFREY GUNTHER.

INTRODUCTION.

Along the banks of the Rito Seco on the western slope of the Sangre de Cristo Mountains in Costilla County, Colorado, there is a belt of auriferous territory of scientific as well as commercial interest which up to the present time has been but little studied,

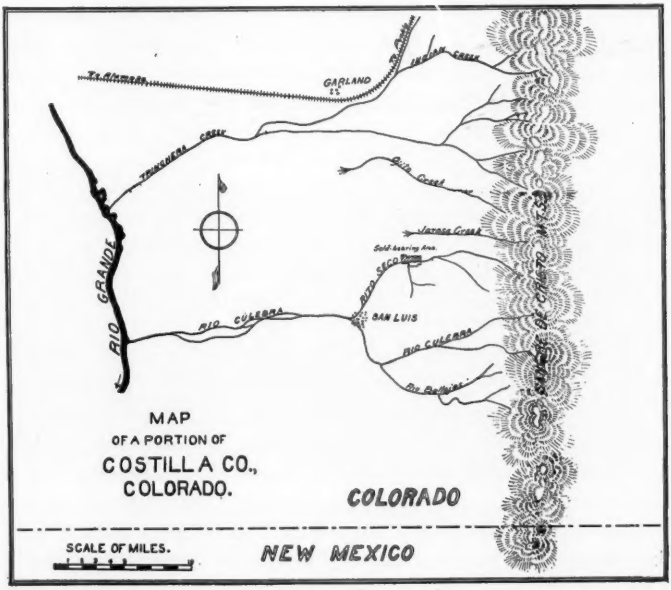


FIG. 4. Map of a portion of Costilla County, Colorado, showing the location of the gold-bearing area.

and never correctly described. The ore bodies which occur in a granite-gneiss, have been exposed over a territory three-quarters

of a mile in length. Their great area and the many diverse forms assumed by the gold bearing material present sufficient points of interest to warrant a detailed description.

Fig. 4 is a map showing the location of these deposits, the auriferous exposures being represented by the hatched area. The Sangre de Cristo Mountains, which here run almost north and south, are shown along the right border of the map; they form the eastern boundary of the San Luis Park, the southernmost and largest of the Colorado plateaus, and are the division line between Costilla and Las Animas counties.

Speculation in the past as to the origin of these ore bodies has afforded vague and unsatisfactory results. Some geologists, formulating theories without the aid of microscopic sections, and basing their opinions on the study of hand specimens only, have pronounced the rocks of the district to be a sedimentary series comprising sandstones, quartzites, shales, etc., whereas the careful study of numerous thin sections under the microscope has proved them all to have been derived from a common original, an extremely metamorphosed and indurated granite-gneiss. This rock has been so completely altered by dynamic action, impregnation and surface agencies, as to leave no clue concerning its original nature except upon examination with the microscope.

GENERAL DESCRIPTION OF THE DISTRICT.

Before taking up the local geology of the ore bodies, a few words as to the general structure of the Sangre de Cristo Range in this district is necessary.

The crest of the range, which at Culebra Mountain reaches an elevation of over 14,000 feet, is composed of a sedimentary series referred to the Carboniferous by Hayden. The marked stratification gives to its profile the serrated appearance from which the range takes its local name, the "Saw Tooth Mountains." This sedimentary rampart rests upon a base of granite and syenite-gneisses, pronounced by Hayden to belong to the Archean. Flanking the range as foot hills are a series of lake beds, referred to the Quaternary by the same authority. The upper and most recent of these consists of rounded and fragmental pieces of the

rocks above mentioned, bound together by a ferruginous cement, whose dark red color gives them an outline, which, although not continuous, is easily traceable. Underlying this and bordering on the plains are lighter colored beds of porous and easily disintegrated sandstone, carrying segregations of coarse material.

The latter beds are tilted at an appreciable angle, and where studied appear to rise with the slope of the cañons. This, together with the fact that the streams are cutting deeper gorges in the cañon bottoms, would seem to indicate that the range has been elevated to a considerable degree within recent times, at least since the early Quaternary.

FIG. 5. View looking down the Rito Seco Cañon.

The photograph given above is a view looking down the Rito Seco Cañon from a hilltop on its south bank. On the right is shown a portion of the gold-bearing territory, and on the left, in the distance, the foot hills of Quaternary sandstones.

A series of lava flows, originating at the volcanic cones which rise boldly from the plain of the San Luis Park, are to be found

low down in the foot hills, and cover a considerable part of the plain itself.

LOCAL GEOLOGY.

The accompanying section is taken approximately parallel to the mountain range. It shows the local distribution of the several rocks in the vicinity of the ore deposits, and the series of transverse faults which, presenting lines of weakness to erosion, have been followed by the streams in the general wearing down

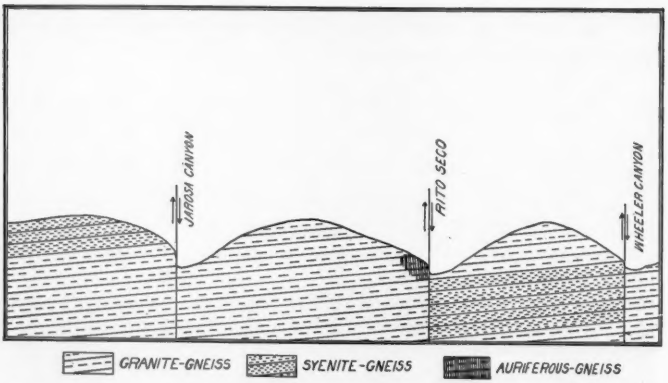


FIG. 6. North and south cross-section through the ore bodies; distance four miles.

of the region. The upthrow side of these faults has been on the north, both escarpments rising almost vertically in places to a height of perhaps 200 feet.

As is to be expected in rocks of such great age, the gneisses are extremely crushed and folded, indications of strain and flowage are everywhere in evidence, and the rock masses are traversed in all directiosn by faults.

The typical granite-gneiss is of light color, and pronounced gneissic structure, in hand specimens orthoclase and quartz are abundant, with the dark silicates almost lacking; in thin section under the microscope, orthoclase, plagioclase, and quartz are abundant, with microcline also present; the principal dark con-

stituent is magnetite, taking the places formerly occupied by other grains, and filling lines of weakness as trains of inclusions; in some specimens biotite is present in small quantity. The rock is characterized by extreme abundance of plagioclase, though a very acid rock, and while it is not considered basic enough to enter the granodiorite class, it leans in that direction. The lack of ferro-magnesian silicates is unusual. The effects of dynamic metamorphism are pronounced, having developed all the usual phenomena of trains of inclusions, bending of mineral plates, faulting of grains, wedge twin bands, and wavy extinction, which are characteristic of the gneisses as a class.

The syenite-gneiss is of far less prominence than the granite-gneiss just described. In hand specimens this rock, which is of pronounced gneissic structure, shows orthoclase and hornblende with generally abundant secondary epidote and garnet. Under the microscope in thin section some plagioclase and quartz is in evidence, with titanite as a prominent accessory. The feldspars are specked all over with flakes of a muscovitic alteration, and all the signs of dynamic metamorphism are present.

Cutting through the granite-gneiss in a northeasterly direction is a series of quartz-porphyry dikes, which, although of wide occurrence, do not appear in the neighborhood of the ore bodies, nor do they seem to have had any connection with, or influence upon their formation. This rock is felsitic in texture and shows no phenocrysts to the unaided eye. Under the microscope in thin section the constituents are seen to be orthoclase and quartz, together with a little muscovite, in a very fine grained groundmass; there is a slight spherulitic tendency, and occasional intergrowths of quartz and orthoclase, which indicate that the rock may be more correctly termed a granophyr. This series of intrusions is evidently of great age, for in most exposures there is no well defined dike and the intrusive is so inextricably mixed with the older rock that its limits are not to be determined with accuracy. Coursing through this rock are veinlets of white quartz carrying fluorite and specular hematite, which minerals are regarded as of pneumatolitic origin. If so, they indicate the presence of fumarolic vapors during cooling, and, it would seem,

tend to connect these dikes with the occurrence of a series of true quartz veins of demonstrably later date than the ore bodies under discussion.

South of the Rito Seco fault there is an exposure of lava capping the granite-gneiss, evidently representing an arm of the outpourings which have been mentioned as being so prominent on the neighboring portions of the plain of the San Luis Park. This rock shows a felsitic groundmass in thin section, with phenocrysts of plagioclase, hornblende and biotite; magnetite is rather abundant and is largely gathered into and around the partially resorbed dark silicates; it has been pronounced an andesite-porphyry. This rock does not occur in the vicinity of the ore bodies, and cannot be considered as having had anything to do with their formation.

GEOLOGY OF THE ORE BODIES.

The ore bodies occur in the granite-gneiss on the north bank of the Rito Seco, and were first discovered along the escarpment before mentioned as forming the north wall of the cañon occupied by that stream. These cliffs, rising abruptly from the cañon bottom, present a section of the ore bodies showing their relations to the containing rock in such a manner as to greatly facilitate their study.

The photograph given below (Fig. 7), shows a portion of this fault escarpment and illustrates the marked topographical difference between the two banks of the cañon, the more distant being the upthrow side.

The following illustration (Fig. 8) is a closer view of these cliffs at a point at which quarrying has been commenced, their entire face here being ore. The faults running in various directions are clearly shown.

Along the Rito Seco dynamic action has been intense, and the granite-gneiss has been further altered until it is not determinable as such except upon microscopic examination. In hand specimens quartz and orthoclase seem to be the principal constituents, together with a greenish grey sericitic product and scattered cubes of secondary pyrite; under the microscope, the rock is seen

FIG. 7. View of fault-escarpment containing the ore.

FIG. 8. Nearer view of escarpment shown in Fig. 4.

to have been originally of coarse texture, many large grains of quartz and feldspar still remain, but most of the rock is thoroughly shattered and altered along the weakened zones to a fine aggregate of secondary products, chiefly sericite. The rock constituents are quartz and orthoclase, plagioclase is next in prominence, and there is a little microcline; some of the slides exhibit a considerable amount of hornblende, generally largely altered to chlorite, and there seems to have been biotite in small amounts. From one-half to two-thirds of the field is covered by the sericitic alteration products. Secondary quartz is in evidence, and there are also many cubes of pyrites. These secondary minerals would argue an impregnation of the original rock after crushing.

The above is a description of the typical ore-bearing rock, which gradually shades into ore as the impregnation with quartz becomes more thorough, and the amount of pyrite increases. The typical ore shows no other minerals than quartz inclosing pyrite, and the greenish grey sericitic product of alteration. Under the microscope little else is disclosed; the quartz is principally of the vein type, though there are many large original quartz grains in a shattered condition.

The transition between the granite-gneiss and ore is gradual. As slides representing all the stages of the transition have been examined, there is but little doubt that the ore merely represents zones in the original granite-gneiss shattered to such an extent that upon impregnation and induration they have lost all resemblance to the mother rock.

In the figures given below Fig. 9 is an ideal section taken at right angles to the plane of the fault, and is an interpretation of the original condition of the ore bodies; the mineralization appears to have been more thorough locally along the fracture, and to have extended into the walls following the crushed zones. Figure 10 is a similar section illustrating the ore bodies as they now exist, and is the basis of Fig. 9. The sharp lines of demarkation between the ore and the gneiss are given thus for purposes of illustration only, the boundaries between ore and waste being by no means sharply defined—one merging into the other so

gradually that where one stops and the other begins is revealed only upon assay.

Specimens of the rock in the transition state have been noted with the feldspars in all states of alteration. As these lose their

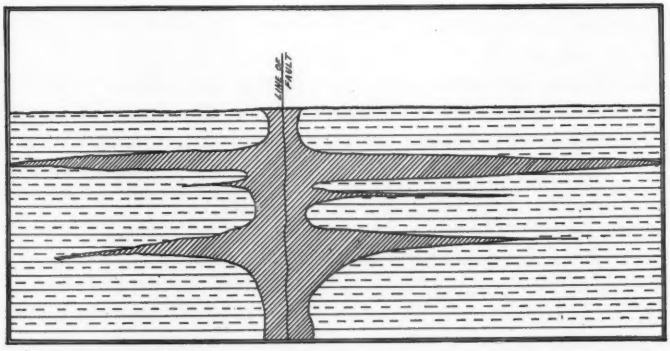


FIG. 9. Ideal section taken at right angles to the plane of the fault, showing supposed original condition of the ore-bodies.

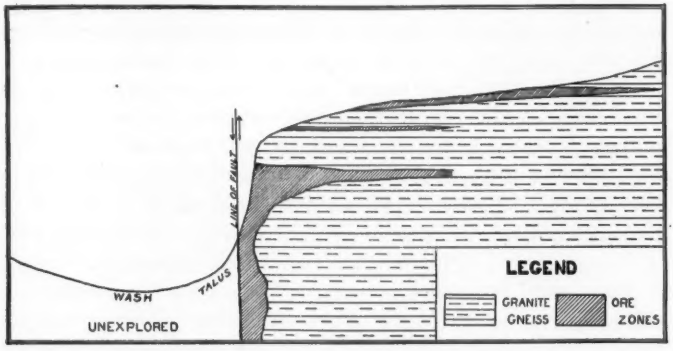


FIG. 10. Actual section showing present condition of the ore-bodies after extensive erosion.

identity, quartz and pyrite become more abundant, until in extreme cases nothing but quartz and pyrite is visible, with occasional patches of a sericitic product representing the last stage

in the destruction of the original constituent minerals. So complete has been this alteration that in the past some areas of the altered granite have been considered to be exposures of true quartzite. Those which contained unaltered feldspar or sericitic material have been termed arkose.

It is a remarkable fact that all the granite-gneiss in the vicinity of the ore bodies, wherever sampled, has assayed from a trace to forty cents per ton in gold; the auriferous contents increasing with the degree of alteration to which the granite has been subjected until in the case of the true ore it carries from $2.50 to $7.00 per ton, and even higher.

The pyrite in general carries gold, but there are many instances where the granite-gneiss contains a large percentage of pyrite without a corresponding increase in gold value,—in these cases, however, the secondary quartz is absent, or present in but small quantity, and it may be safely inferred that the presence or absence of secondary quartz determines whether the material be ore or waste.

The crushed granite softens on weathering and when not protected by silicification, the pyrite decomposes, coloring the mass a yellowish tint, and dendritic pyrolusite appears on the plains of fracture. The ore is much more resistant. The decomposing pyrite colors the mass, but beyond this and a local softening of the sericitic material there is little change. As might be expected, the crushed granite-gneiss in the neighborhood of the ore bodies has become softened on weathering and eroded away, leaving zones of the more resistant ore to form the present surface; this has been the case to such an extent that upon superficial examination the entire hill might seem to be composed of ore.

Penetrating the ore and granite-gneiss alike is an extensive series of true quartz veins. These carry the typical vein minerals, galena, zinc-blende, and chalcopyrite, together with fluorite and specular hematite, the last two indicating the presence of fumarolic vapors at the time of vein filling.

At first the existence of these veins would seem to indicate that they played an important part in the mineralization of the ore zones, by distributing the gold-bearing solutions through

the rock mass. This has not been the case, however; these veins run through both the ore and the granite-gneiss, the ore is not richer in their proximity than it is at a distance from them, and they have not enriched the granite-gneiss beyond the few cents per ton which it seems to carry throughout its mass. The metallic sulphides and fumarolic minerals mentioned as occurring in these veins are lacking throughout the mass of the ore, and as a further proof, the veins themselves, where sampled, assayed but a few cents per ton.

It is from such a deposit which was of sufficient size and richness to have been worked for its galena contents, that the district took its name,—" Plomo," Spanish, meaning lead.

INTERPRETATION OF GEOLOGICAL HISTORY.

As a general summary, the geological history of these ore deposits may be stated as follows: the ore bodies occur in the granite-gneiss which forms the base of the Sangre de Cristo Range. The extreme dynamic action to which the original granite has been subjected formed zones of weakness and permeability along certain horizons in the rock mass, the present ore bodies representing such a zone or zones lying near the surface, which from this very permeability afforded ready ingress to the ore bearing solutions, and from their position, the necessary conditions of lowered temperature and pressure to facilitate deposition of the dissolved material.

On the elevation of the mountain range, a series of east and west faults took place, of which the Rito Seco fault is an example. Through the Rito Seco fault came up solutions carrying gold; these attacked the biotite and feldspars in the crushed zones in the granite-gneiss, probably by a general and long-continued seepage, destroying and altering these minerals and depositing gold and pyrite, with silica cementing the whole mass.

On a further disturbance of the district, probably accompanying the intrusion of the quartz-porphyry dikes, a series of cracks and fissures were formed through the ore and the original granite-gneiss alike. Through these fissures were introduced solutions and vapors, forming the quartz veins which carry the pneuma-

tolitic minerals. This mineralization followed after and had no connection with the original mineralization of the shear zones.

Further dynamic action caused faulting and folding, thus complicating the geology.

Finally, the outpouring of the recent lavas, the deposition of the lake beds and recent wash, and a possible surface silicification due to organic agencies, bring the geological history of the Plomo ore bodies down to the present time. In closing the writer desires to express his acknowledgment to Dr. W. L. Austin and Dr. C. P. Berkey for friendly advice in the preparation of this paper.

THE QUICKSILVER DEPOSITS OF BREWSTER COUNTY, TEXAS.

WILLIAM BATTLE PHILIPS.

GENERAL STATEMENT.

The first authentic discovery of the quicksilver deposits of Brewster County dates from 1894. Rumors, it is true, of the existence of cinnabar in the southern part of the county were in circulation as early as 1887, and it has even been ascertained from some old settlers in Presidio County that such stories were rife about 1850 when the country was remote and infested by Indians, but these have little other than a historic interest.

So far as known Mr. George W. Wanless, of Jimenez, Mexico, and Mr. Charles W. Allen, of Socorro, New Mexico, were the first Americans to visit the region and to locate claims.

Although a short notice had previously appeared in the *Bullion,* Los Angeles, California, in August, 1894, and another at about the same time in the *Manufacturer's Record,* Baltimore, the first really scientific description of the country was that by Professor W. P. Blake in the *Transactions of the American Institute of Mining Engineers,*[1] Vol. XXV., 1895. Mr. H. W. Turner later described the region in the Twenty-first Annual Report of the United States Geological Survey.[2] In the *Engineering and Mining Journal,* Vol. LXXI., Mr. E. P. Spalding has spoken of the deposits, and Mr. Robert T. Hill, in the same journal, Vol. LXIV.

Here the matter rested until the fall of 1902, when the University of Texas Mineral Survey, under the direction of the present writer, issued its Bulletin No. 4, entitled " The Terlingua Quicksilver Deposits, Brewster County, Texas," in which Mr. Benjamin F. Hill described the deposits in detail. Since that time other articles have appeared in the *Engineering and Mining Journal,* the *Mining Magazine* and descriptions of the three new

[1] *Trans. Am. Inst. Min. Eng.,* Vol. XXV., 1895, pp. 68–76.

[2] Twenty-first Annual Report of U. S. Geological Survey, Part VI., pp. 279–280.

oxychlorides of mercury in the *American Journal of Science*. These articles were communicated by B. F. Hill, Morris P. Kirk, James W. Malcolmson, and the present writer.

The quicksilver deposits are located in the southern part of Brewster County about three hundred miles southeast of El Paso, and one hundred and ten miles south of the line of the Southern Pacific Railway, and from seven to fifteen miles north of the Rio Grande River.

The country is an arid one, offering but few attractions to those not interested in some special enterprise. A general view of the region may be seen in Plate IV.

The country rocks include both eruptives and sedimentaries, both classes embracing a series of rocks which show considerable variation in lithological character.

The sedimentaries include limestones, marls, chalks, shales and clay. They are sometimes tilted to an angle of 24°, but departure from a horizontal position, while often observable, is usually not of very marked degree. The rocks have been dissected by erosion into the usual buttes and mesas so characteristic of regions of limited rainfall. An outcrop of horizontal strata may be seen in the illustration, Plate VII, which shows an exposure of the Eagle Ford shales. The igneous rocks occur as necks, plugs, laccoliths and sheets, the horizontal forms predominating and may be seen occupying the tops of many of the hills and mesas.

Their thickness often amounts to two or three hundred feet. A detailed investigation of their microscopic character has not yet been made, but they probably include rhyolite and phonolite, and further study will undoubtedly reveal an eruptive series of unusual interest.

The geological age and general character of the several rock formations may be better understood from the following table:

Formation.	Thickness in feet.
TERTIARY.	
Igneous Rocks.	
UPPER CRETACEOUS.	
Ponderosa Marls	200 to 300
Austin Chalk	100 to 150
Eagle Ford Shales	500 to 800

GENERAL VIEW OF THE QUICKSILVER DISTRICT AT BIG BEND, BREWSTER COUNTY, TEXAS.
(PHOTO. BY W. B. PHILIPS, SEPT., 1905.)

GENERAL VIEW OF THE QUICKSILVER DISTRICT AT BIG BEND, BREWSTER COUNTY, TEXAS.

(PHOTO. BY W. B. PHILIPS, SEPT., 1905.)

LOWER CRETACEOUS.

Vola Limestone	75 to 100
Arietina Clay	75 to 100
Washita Limestone	100 to 200
Fredericksburg Limestone	1000 to 1200

Topographically and geologically the district is divisible into two parts, what is known as the Vogel Draw being the separating line. West of this Draw and between it and Fresno Cañon are the heavy limestones of the Fredericksburg and Washita formations which have been exposed by the removal of the overlying series, while to the west, as far as Rough Run, are the shales of the Eagle Ford and the coal-bearing sandstones of the Cretaceous.

By far the larger amount of the metal obtained up to the present time has been secured from deposits in the limestones belonging to the Washita and Fredericksburg formations. Of the total production of some 20,000 flasks (at 75 pounds net), not less than 17,000 have come from these limestones. Within the last two years, however, prospecting in the Eagle Ford shales has been actively carried forward with the result that many promising discoveries have been made and a very considerable quantity of rich ore taken out and treated.

In the limestones the productive area is about twenty-five miles square; in the shales mining is restricted to a butte six miles long by half a mile wide, the shales not having yet been as thoroughly prospected as the limestones. It is advisable to use the term *Terlingua District* when speaking of the limestones and *Study Butte District* when speaking of the shales. No mining is carried on in the sandstones although there is reason to believe that in some places, at least, cinnabar may be found.

The exact relations of the igneous flows to the cinnabar has not yet been determined. At one locality, on the eastern edge of the proven field the ore occurs as stringers and small pockets in rhyolite and is closely associated with pyrite. Towards the western edge it has been found in close association with andesite and phonolite.

THE TERLINGUA DISTRICT.

The Terlingua district, confined almost entirely to the Lower Cretaceous, is characterized by an enormous development of heavy, close-grained limestones in which are many caverns and lesser openings. The cinnabar is carried by veins of calcite, frequently of fine crystallization, with which gypsum is plentifully intermixed. Some of the caverns are lined with calcite, as stalactites, etc., carrying cinnabar, others show considerable gypsum and this is often crystallized in fantastic shapes. The limestones carry not only cinnabar but native quicksilver together with the three oxychlorides, *terlinguaite, eglestonite* and *montroydite*. No native quicksilver nor any oxychloride are found in the shales of the Upper Cretaceous. On the other hand, the bituminous compounds which accompany the cinnabar in the shales are not found in the limestones. At more than one locality in the Terlingua district considerable masses of cinnabar have been found in piles on the floors of caverns which have no visible outlet to the surface. One such cavern was encountered at a depth of forty-five feet from the surface and was twenty-five feet high, sixty feet long and forty feet wide. On the floor of this cavern there were piles of cinnabar carrying more than 30 per cent. of quicksilver, some of the pieces exceeding 50 pounds in weight. Stringers of rich ore made out in many directions from the caverns and the stalactites were in numerous places coated with cinnabar. Within a mile of this place a similar cavern was found also with piles of rich cinnabar on the floor.

In the Terlingua district the thickness of the ore-bearing horizon (Lower Cretaceous limestones) appears to be between 1,200 and 1,500 feet, but no investigations of its nature have been made, even with a bore-hole, below a depth of four hundred feet. The limestones are, however, cut by deep and narrow cañons, whose vertical walls afford fine sections. One of these cañons, from seven to twelve miles south of Terlingua postoffice, is known as the Grande Cañon of the Rio Grande (Rio Bravo del Norte of the older maps) and it has been well described by Robert T. Hill in the *Century Magazine,* January, 1900. Its length is about four-

teen miles, from below Lajitas to the mouth of Terlingua Creek, the descent in this distance being about two hundred and fifty feet. The walls are almost vertical, in some places exceeding 1,200 feet, and the width varies from 600 to 1,000 feet. The river flows at the bottom and in time of great flood, as for instance in August, 1904, an enormous volume of water rushes down the cañon with frightful velocity, ejecting stones and drift wood from the mouth as from a huge cannon.

The limestones, as well as the shales, have been subjected to a remarkable erosion, for while the annual rainfall in the district does not exceed fifteen inches, practically three-fourths of it occurs during the months of June, July and August. Taking the average elevation of the quicksilver district proper at 3,000 feet and the elevation at the mouth of Terlingua Creek, into which most of the water courses of the district drain, at 2,200 feet, the average slope of the region is about eighty feet to the mile. This is inclusive of the extensive flats that intervene between the plateaus and the river and which are now occupied by the detritus from the higher ground. In the plateau region itself the slope is much more rapid and the results of erosion on a grand scale are much more apparent.

The practical effect of this extensive erosion, in so far as concerns the quicksilver deposits, has been to expose the formation in a series of vertical sections, most useful in the study of economic relations.

In the limestone the cinnabar occurs in calcite veins whose general trend is northeast to southwest. These veins do not all carry pay ore throughout their course, but appear to be stringers connecting pockets of greater or less extent, and of varying richness. It not infrequently happens that the walls close up on the veins, squeezing them out and leaving what is known as a *pegason, i. e.,* a thin parting between the walls. The pegason may or may not carry particles of cinnabar but whether it does or not it is followed as an indication of ore.

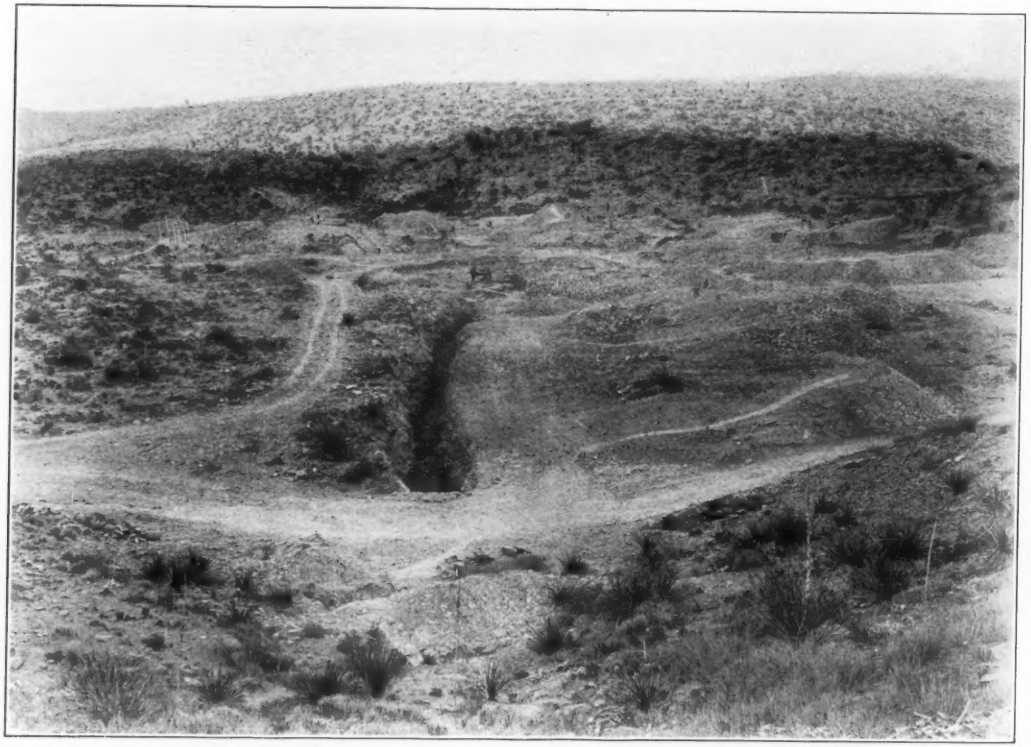
The calcite veins do not seem to possess any regularity of dip, although in parts of the district a distinct northwest inclination can be observed, while in other places the dip is towards

the southeast. Mining operations, for the most part, are conducted near the surface, the deepest shaft being about two hundred feet. By far the greater portion of the ore is obtained from shallow workings, trenches, pits, etc., by windlasses, horse-whim, or gasolene hoist. (See Plate V.) Active prospecting must be carried on by a regular gang, the ore being graded by means of the horn spoon and the results checked by assay. Some of the prospectors become very expert in grading ore with the spoon, the results running to within two-tenths of one per cent. of the regular assay. The most convenient form of apparatus for assaying these ores is that designed by Mr. W. W. Whitton, chemist for the Presidio Mining Company, Shafter, Texas. It consists of a steel cup, holding the mixture of ore and iron filings, on top of which is clamped a silver plate, kept cool by water in a steel cup. With a single apparatus of this kind and a gasolene burner one can make from fifteen to twenty assays in a day, the limit of accuracy being less than 0.05 per cent. The quality of the ore sent to the furnaces, which are of the Scott type, varies within rather wide limits. One of the largest furnaces, taking now sixty tons a day, is running on material of about 0.75 per cent. mercury. (See Plate VI.) Other furnaces receive material of higher grade, the mixtures seldom falling below 1.50 per cent., and not infrequently going to 2 and 2.50 per cent. A few iron retorts are operated, but these have not been profitable with ore under four per cent. of metal.

The consumption of wood, as fuel, ranges from 1.50 to 2 cords per day of twenty-four hours for a furnace treating twenty to thirty tons of ore. The delivery price of wood; cotton-wood, mesquite, oak, piñon, etc., varies from $5.50 to $7 a cord, the tendency being towards the higher price. Some interest is now manifested in the possibility of using producer gas for fuel, a fair quality of coal now offering at $6 and $6.50 a ton.

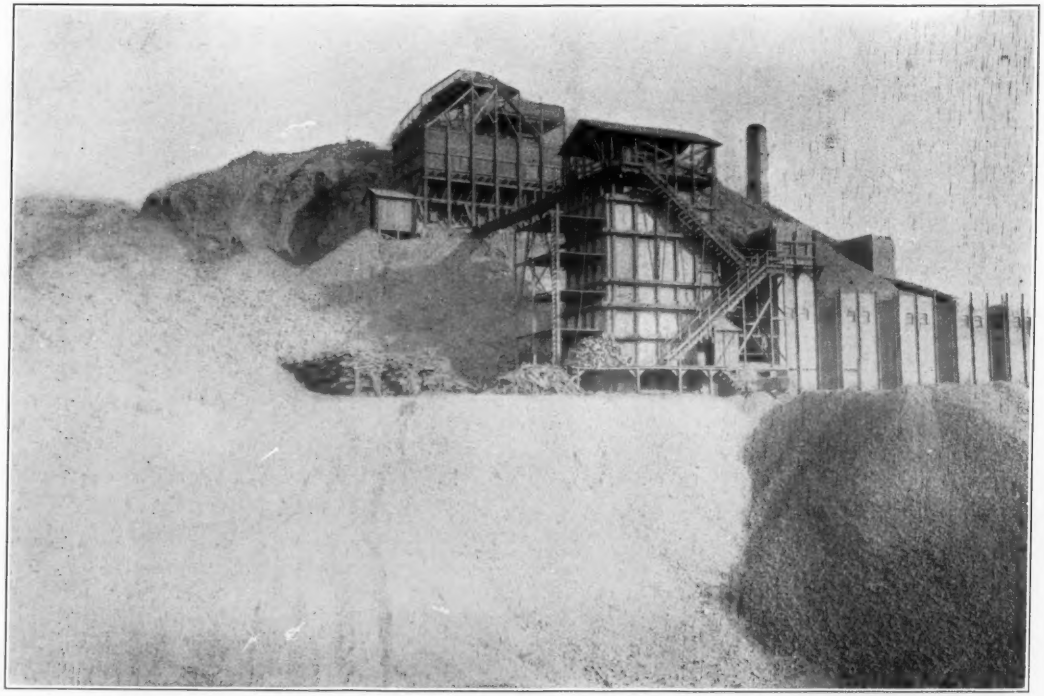
STUDY BUTTE DISTRICT.

Mining operations in the Upper Cretaceous shales and thin bedded limestones, between Vogel Draw and Rough Run, have not been carried on so extensively as in the heavy limestones



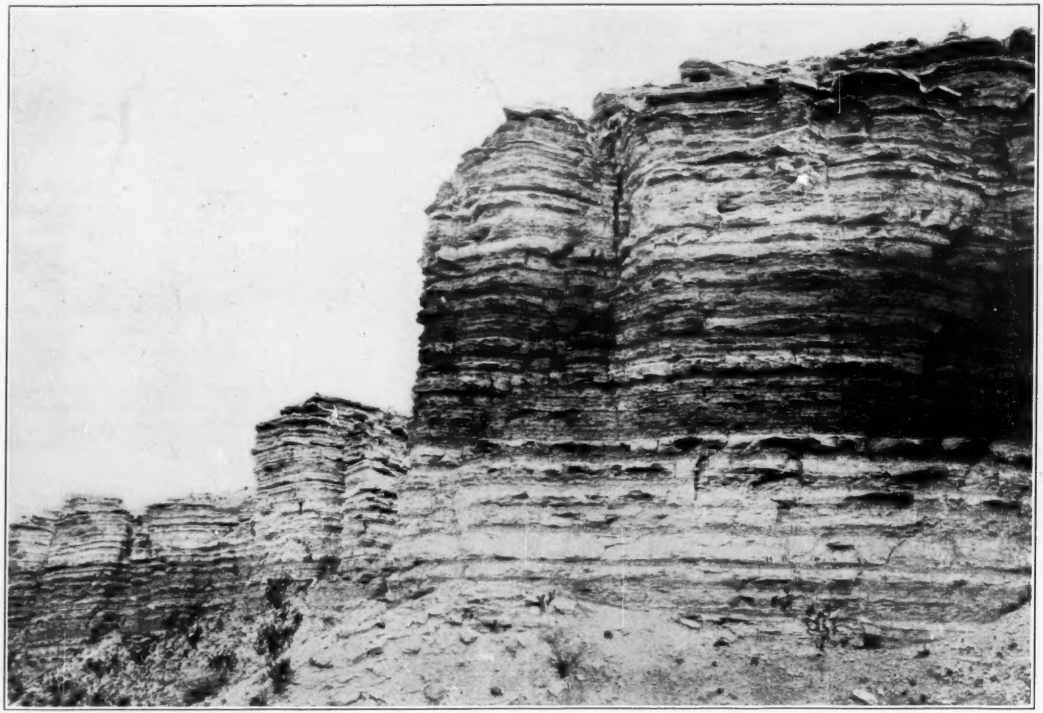
TERLINGUA QUICKSILVER DISTRICT LOOKING EAST FROM CALIFORNIA HILL.

(PHOTO. BY W. B. PHILIPS, AUGUST, 1905.)



A 60 TON QUICKSILVER FURNACE. BIG BEND CINNABAR MINING COMPANY, BIG BEND, BREWSTER COUNTY, TEXAS.

(PHOTO. BY W. B PHILIPS, AUGUST, 1905.)



EXPOSURE OF EAGLE FORD SHALES (UPPER CRETACEOUS) ALONG TERLINGUA CREEK, BREWSTER COUNTY, TEXAS.

(PHOTO. BY W. B. PHILIPS, JULY, 1905.)

of the Lower Cretaceous, between Vogel Draw and Fresno Cañon, but indications are not lacking that these shales may later prove to be the chief source of supply for the quicksilver industry. They are much more cheaply mined, are traversed by a stream of permanent water (Terlingua Creek), and are within easy reach of the coal deposits along Rough Run and Terlingua Creek. A typical exposure of Eagle Ford shales is shown in Plate VII. The cinnabar-bearing shales are held between two sandstones, the lower being water-bearing, while the upper carries a fair quality of coal. Proceeding south from Cigar Springs within a distance of two miles one crosses the cinnabar-bearing shales and comes at once upon the coal-bearing sandstones. The dip of the sandstones is twenty-four degrees southeast, at Cigar Springs, and this dip is also that of the overlying shales and of the upper sandstone.

It is likely that the lava (nepheline bearing?) now seen in Cigar Mountain and along the trail from Cigar Springs to Vogel Draw at one time was much more extensive than at present, and may have covered a considerable area west of Cigar Mountain, for the remains of lava beds are even now to be seen at more than one locality. At Study Butte, two miles south of east from Cigar Mountain, active mining is carried on in the lava (rhyolite) which overlies the Eagle Ford shales as also in the shales themselves. On the top of Christmas Mountain, twelve miles north of Study Butte, cinnabar is closely associated with porphyry and at this locality has been found the only occurrence of quartz in association with the ore that is to be seen anywhere in the district. In the rhyolite of Maverick Mountain, Croton Spring, etc., stringers of cinnabar are to be observed. Near California Hill, in the heart of the Terlingua district, there is a notable occurrence of andesite and many promising finds of cinnabar have been made in the immediate vicinity.

Perhaps the relation between the lava flows and the occurrence of cinnabar is more apparent in the Study Butte district than in the Terlingua district. At any rate there is scarcely a deposit of cinnabar in the shales that is not in immediate proximity to a lava flow, as for instance, on Sections 295, 248 and 216, Block

EXPOSURE OF EAGLE FORD SHALES (UPPER CRETACEOUS) ALONG TERLINGUA CREEK, BREWSTER COUNTY, TEXAS.
(PHOTO. BY W. B. PHILIPS, JULY, 1908.)

G 4, and in numerous other localities. The presence of cinnabar in the rhyolite shows that the ore is at least of later origin than this variety of eruptive rock.

Investigations are now in progress looking towards the determination of the particular kind of lava that accompanies each deposit of cinnabar. It may not be doubted that there is a close relationship between these flows and the deposition of the ore, but the data for the further elucidation of this problem is not yet at hand.

The development of the quicksilver industry in Brewster County has progressed in spite of the unreasonable and foolish restrictions imposed by the Texas mining laws, but the time has now come when further developments are not to be anticipated unless there is a marked improvement in the conditions under which the public lands may be prospected and mining property acquired.

OCCURRENCE OF ALBITE IN THE BENDIGO VEINS.

WALDEMAR LINDGREN.

The feldspars are not, as a rule, minerals of common occurrence in metalliferous veins, and new finds of such an association are therefore worthy of record, especially as they may emphasize the connection of certain classes of deposits. The discovery of albite in intimate intergrowth with quartz from the gold-bearing veins of Bendigo, Australia, in this case tends to confirm the intimate relationship of the Victorian deposits to the gold-quartz veins of California.

As is well known, the veins of Bendigo are contained in a highly compressed series of Ordovician black clay slates which, a short distance south of Bendigo, are invaded by a batholith of granite or quartz-monzonite.[1] The deposits take the peculiar form of *saddle reefs,* that is, the bodies of pay quartz are chiefly contained in the anticlinals of clay slate or associated beds of fine-grained sandstones, and form bodies of lenticular shape that are bent over the axial lines of these anticlinals. They extend continuously along the axes for several miles, conformable with the bedding in a general way; they follow the pitch of the anticlinals, and their extensions, generally parallel to the strata on both sides of the saddle, are called the legs. Ten or more of these saddle reefs may be formed one above the other on the same anticlinal axis. There are three of these principal axes or "lines" at Bendigo within a distance of 4,000 feet; they are parallel, striking northward, and are known as the New Chum, Garden Gully and Hustler lines. Besides the saddle reefs the slates also contain many large "spurs" or "makes" which are irregular, often flat veins of great size, more or less directly

[1] The structural features have been excellently described by E. J. Dunn, Report on the Bendigo Gold Field, Department of Mines, Melbourne, 1896, and by T. A. Rickard, *Trans. Amer. Inst. Min. Eng.*, 1891, Vol. XX., pp. 463–545.

connected with the saddle reefs. At many places, especially in the northern part of the field, these spurs are rich.

The district has produced about 6,000,000 ounces of gold from quartz mines, and about 14,500,000 ounces from quartz and alluvial mines. In 1904 the production was 206,000 ounces, the ore averaging $10 per ton.

Another feature of interest is the depth attained in the mines. Many of them are over 3,000 feet deep, and recently the New Chum railway mine has attained 4,156 feet, at which depth a saddle reef was met of probably payable character,—that is a minimum of $7 per ton. On the whole, however, the upper 2,500 feet appear to be considerably richer than the lower parts of the mines.

The gold-bearing quartz of the Bendigo deposits is sharply separated from the black slates, as may be well seen from the excellent photographs in Mr. Dunn's monograph. There is no replacement of the country rock by quartz; the opposite sides of the jagged walls of the "spurs" in many cases would fit closely if joined again. The quartz is milk white and almost glassy; it would be regarded with much disfavor by many miners of this country and contemptuously designated as "bull-quartz." Extremely little evidence of pressure and crushing is seen. Quartz with thin intercalated sheets of slate is not uncommon, and this occurrence as well as many other facts lend much support to the view, also advocated by Mr. Dunn, that the expanding force of crystallization has aided in creating the necessary cavities for deposition. Carbonates containing lime, magnesia and iron in places mingle with the quartz and very frequently line the walls of the fissures. To some extent these carbonates also replace the slate adjoining the veins. Chlorite is sometimes found embedded in the quartz to which it imparts a dark greenish tinge. It is well crystallized in minute bent and curved prisms. The sulphides are generally limited to pyrite and arsenopyrite, with a little galena. The two first-named minerals seem most abundant in the slate immediately adjoining the quartz. At the contact cubes of pyrite are sometimes seen, of which one half is embedded in quartz and the other half in the black slate.

The albite was found by the writer in the main body of gold-bearing quartz mined at a depth of 1,000 feet, in the South New Moon mine, one of the most productive properties on the northern extension of the Garden Gully line near Eagle Hawk. The ore does not occur as a saddle reef, but as a large "spur" or wide, irregular gash in the black slates. The gold is coarse and may be frequently seen in large particles in the massive white almost glassy quartz, sharply contrasting against the black slate which it cuts. Small drusy cavities are rather common and in some of these the albite was detected. It forms in part anhedrons intergrown with the quartz and also well developed crystals up to 8 or 10 mm. long, of stout prismatic form and projecting into the vuggs together with quartz crystals of ordinary form. Distinctly later yellowish crystals of calcite sit on quartz or albite, and all three minerals are dusted with minute pyrite crystals. Dr. W. T. Shaller, to whom I am indebted for the examination of the crystals, states that the following forms are present: $b = 0\bar{1}0$ large face; $i = 1\bar{5}0$ very narrow face; $z = 1\bar{3}0$ medium size face; $M = 1\bar{1}0$ small size face; $f = 130$ medium size face; $m = 110$ medium size face; $c = 001$ large size face (cleavage); $x = \bar{1}01$ narrow face; $y = \bar{2}01$ narrow face; $n = 0\bar{2}1$ narrow face; $\gamma = \bar{1}12$ small face; $p = \bar{1}11$ small face; $\delta = 1\bar{1}2$? narrow face.

The prism zone is very striated, making the readings uncertain. The *b* face is very large and the crystals are somewhat flattened parallel to this face. The crystals are twinned according to the albite law. Frequently they consist of three individuals, as clearly seen on the basal plane, but sometimes the twinning is more complicated.

A number of occurrences of feldspar in veins have recently been brought to light. A review of these emphasizes several noteworthy facts. In the first place soda-lime feldspars appear to be entirely absent; at least the writer is not aware of any well authenticated instance. Albite is frequently reported, but seems to be confined to older gold-quartz veins, such as the Mother Lode deposits of California, the Douglas Island mines of Alaska, and the Victorian quartz veins. Orthoclase of the variety adu-

laria, sometimes also referred to as valencianite, is apparently common in the gold or gold-silver veins occurring in Tertiary lavas. Recently described examples of this are found in the Silver City and De Lamar districts, Idaho; Cripple Creek, Colorado; Tonopah, Nevada; and Waihi, New Zealand. If these tentative generalizations are true they may prove of some importance, and possibly the kind of feldspar resulting is in some way dependent upon the depth at which it was deposited. In general, the last-named deposits were formed much nearer to the surface than were the gold-quartz veins of California and Victoria.

There are several large classes of veins in which no feldspars have thus far been found. Among these are the copper veins of Butte and Clifton and the silver-lead veins of the Coeur d'Alene and Wood River types in Idaho.

DISCUSSION.

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

What is a Fissure Vein?

Sir:—We owe the early conceptions of ore-deposits to the Cornish and Saxon miners, more than to any other observers. It is, of course, true that mining was carried on quite extensively by the Romans in the countries around the Mediterranean and by other southern Europeans, but nevertheless when sound geological principles began to be established in the eighteenth century their recognition was due in great degree to the Saxons and the Cornishmen. Geological science at large is likewise greatly indebted to them, and mining geology may be truly said to have been founded by them. From Cornwall and Saxony the pioneer miners radiated to all parts of the globe and carried with them the ideas gained from experience at home.

It happens that in Cornwall and Saxony the veins are prevailingly fissure veins in the strictest sense. De la Beche, writing in 1839, in his classic report upon Cornwall, Devon and West Somerset entitled the chapters in which he treats of the veins "Mineral Veins and Faults."

In Saxony the dislocations are no less sharply defined and, except for the stockworks of the tin mines, they constitute the chief type of ore-body to which attention was paid.

What result could be more natural, therefore, than that miners and prospectors should always have in their minds during their work of extraction or of search, the conception of a fault-fissure or at least a fissure without necessary faulting, which should extend to indefinite but great depths and which should contain

valuable deposits of ore? The sharply defined veins of the old countries gave all desired support to the idea and experience, hopes and desires alike combined to strengthen it. The fissure veins were believed to continue to the profound depths of the earth, even to the "ewige teufe." This idea also had much to do with establishing the phraseology of the United States law, and was largely instrumental in bringing to pass the unfortunate confusion which has gathered around the deplorable apex litigation of the western districts.

When, however, we come to sharply define a fissure vein, clear as our thought may be regarding the general conception, we find difficulties. There are many small veins in cracks of no great extent, such as joints. Originally they might have been properly described as small fissures; shall we group them as fissure-veins when filled? Obviously in so doing we would contradict the time-honored conception which involves extent and depth among its fundamentals. Can a gash vien, so acutely defined by J. D. Whitney, and limited laterally and below to a single stratum, be considered a true fissure vein, even though at times quite large? Obviously not in accordance with the old standards, otherwise the distinguished author of the term would not have introduced it. Nor again does the term properly apply to a series of small, imbricating veins along a line of dislocation such as G. F. Becker has described os "linked-veins" in the endeavor to translate the German "Gang-zug."

On the contrary, so far as we use "fissure vein" to-day or "true fissure vein," the term should be alone applied to a vein deposited in a fissure extended in its longitudinal dimension and continuous below to the depths reached by faulting, unless cut off by other faults. Practically this means a fault-fissure because one cannot conceive of a fissure of this extent being produced without sufficient displacement to constitute a fault.

No one, however, who is familiar with the wide range of shape, size and origin presented by the ore-bodies worked to-day can longer attach the same importance to fissure-veins which was felt by our predecessors in earlier generations. Although they have been revealed in surprising perfection in many mines, yet

the replacements, the impregnations, the contact-zones and the several other irregular deposits have so extensively proved to be the sources of our ores that fissure veins are scarcely if at all more abundant or more productive than any one of these other types.

J. F. KEMP.

Sir:—1. I think there is no doubt that this question, if it simply calls for the definition of a fissure-vein, would be sufficiently answered, to universal acceptation, by the statement, "A fissure-vein is a mineral mass, occupying a fissure in the earth's crust." This general definition is independent of the nature of the vein-material (metalliferous or otherwise); its difference from the country-rock (for instance, there may be fissure-veins of lime in limestone, or of granite in granite); and the manner in which the fissure was filled (by intrusion of molten material; sublimation; pneumatolytic action; aqueous deposition of mechanically suspended material; precipitations from solutions, ascending or descending; lateral secretion, magmatic segregation, etc.). The only essential proposition involved in the definition is that the mineral deposit must have begun in a pre-existing fissure.

2. But if the question covers also the systematic relations and importance of the deposits classified as fissure-veins, it should be said that true fissure-veins are not as important as they were once held to be, because:

a. They are now recognized, in many instances, as subordinate features of larger mineral masses, the interstices of which have been genetically equivalent to the space of the fissures themselves, so that the whole of such a mass must be regarded as an aggregate of cavities, filled with mineral.

b. Many deposits, apparently "fissure-veins," have been found to be the result of slow replacement, impregnation or alteration of zones which cannot be regarded as having at any time presented open fissures.

c. The largest producing mines of the world are now based upon deposits which never could have been classed as "fissure-veins"; and hence the leading position assigned to such veins

by the "Saxon school" (from Agricola to Cotta), while they constituted the principal source of certain metals, no longer belongs to them.

d. The essential characteristic of fissure-veins is one of form, as the classic text-books, with their discussions of strike, dip, walls, faults, etc., abundantly show. By many authors (including myself, in my report of 1870 as U. S. Commissioner of Mines and Mining, p. 448) they are placed under the head of sheet, or tabular deposits; and such a conception underlies the provisions of the U. S. mineral land law. But this was never exclusively significant, even in the art of mining. A bed, tilted and bounded like a true vein, would be mined in the same way. From a scientific standpoint, on the other hand, the origin and nature of any mineral deposit are not to be deduced from its form alone; and fissure-veins, in a genetic classification, necessarily occupy subordinate divisions under the general head of secondary or subsequent deposits, and under separate sub-headings denoting the manner of mineralization. In other words, they do not constitute a leading class by themselves.

3. Nevertheless, there is, in my judgment, a group of fissure-veins, which deserves a higher rank as a separate class. I refer to veins of deep-seated origin, entirely different from the country-rock enclosing them, and not extending, as impregnations, etc., into the rock, or attributable to such action proceeding from it. The importance and extent of this class may be at present more or less doubtful; but I think it will permanently remain and demand recognition in any general theory of ore-deposits, because it presents, besides the characteristic of form, peculiar features of structure and probable origin. Such deposits have always been known as fissure-veins, and, as they have been distinguished from sundry other deposits resembling them (gash-veins, contact-zones, shear-zones, etc.) this original name has been made more definite by adding the word "true." With some such modification, perhaps, I think the name should survive. It is always a pity to break the continuity of technical literature by unnecessarily killing a familiar term. This process is sometimes necessary; and it is, in my judgment, always better than the retention

of an old term with a distinctly new meaning. For instance, it would be better to drop the term "fissure-veins" altogether than to apply it to something which would never have been so called by the classic authors who invented that term. But a mere restriction of the class, taking out deposits (shear-zones, etc.) which were once included in it, but leaving those which now, as always, properly belong to it, does not warrant the abandonment of the name. New births, of course, require new christenings; and the genealogies of science should not be confused by giving to the little strangers the names of their ancestors. There are some terms in modern geological literature which really ought to be followed by "Jr." But, on the other hand, when the ancestor still survives, albeit somewhat shrunken with age, he ought not to be mistaken for a baby, and re-baptized!

4. This leads me to say a final word concerning the classification of mineral deposits. The text offered for this symposium seems to me to be little more than a question of classification; and, after more than forty years of study, I am inclined to say, as Thackeray's Jeames Plush said of orthography, "As for classification, every gentleman has his own!"

For a logical classification requires a primary division, based upon the deepest and sharpest distinction that can be found, and a series of subdivisions, based upon less profound and, perhaps, less sharply defined differences—which should be, however, successively less important and duly subordinate to those which precede them. Moreover, the members of each rank should be equivalent in importance, as measured by the principle of the classification; and vagueness of distinction should be, if possible, confined to the last series (corresponding to "varieties" in biology).

Now, in the classification of mineral deposits, we encounter at the outset the difficulty that the basis of the profound primary division depends upon the purpose of the classification. From the standpoint of the art of mining, perhaps the most radical distinction is between superficial and underground deposits; and classifications based on this distinction are doubtless most convenient for instructors in the processes and methods of

that art, who naturally follow this primary division with others based upon form, position, contents and structure, rather than genesis—which does not greatly concern the mining engineer, except so far as it may be a guide to the discovery, valuation and exploitation of mineral deposits.

On the other hand, a logical classification is conceivable from the standpoint of descriptive geology, arranging the deposits according to what they now are or contain, without primary distinctions as to how they acquired their present characteristics. Such a system might begin with a division into metalliferous and non-metalliferous deposits; or deposits in igneous, in metamorphic, and in sedimentary rocks; or deposits contained in the rocks of different formations.

No doubt the most scientific classification should be a genetic one; and for this purpose, probably the best practicable primary distinction is the one long ago proposed by Werner of Freiberg, between "contemporaneous" and "subsequent" mineral deposits. Yet it is conceivable that a still deeper and older distinction may be established hereafter, to which mineral deposits, like all other parts of the earth's crust, will be properly subject. Meanwhile, it seems to me that our classifications will continue for a considerable period to express the several purposes for which they are made, and the notions of the makers as to the relative general importance of the differences they represent; while the most important service that any investigator can render will be the accurate observation and adequate record of the facts required for larger induction and ultimate theory.

R. W. RAYMOND.

Structural Features of the Joplin District.

DISCUSSION OF PAPER BY C. E. SIEBENTHAL.

Sir:—Through the courtesy of Mr. Siebenthal I am given this opportunity of discussing the very interesting series of observations recorded in his paper on the "Structural Features of the Joplin District." As he has shown, the determination of the amount of faulting present in the Joplin district is a matter of considerable economic as well as scientific importance. The wide

divergence of opinion which has heretofore prevailed is somewhat more explicable in the light of Mr. Siebenthal's observations. In my own earlier work in the district, in 1900, I was led to believe in the presence of faults of one hundred to one hundred and fifty feet or more at a number of points. The reasons for this belief were essentially the same as might follow from a study of Mr. Siebenthal's sections I and IV if the intervening sections were absent. Very similar conditions were observed on the Continental tract, at Oronogo, at Aurora and elsewhere. With the clear evidence of faulting, the pronounced brecciation, the sheeting of the rock parallel to the contact and the very common coincidences of the fault with the boundary line and of the shale, there seemed no escape from the conclusion that certain shale patches at least occupied depressed areas due to faulting; this despite the recognition of the presence of a marked unconformity between the shale and the limestone and a great readiness to blieve in pre-Coal Measure erosion channels such as I had previously described in Iowa.[1] The explanation was, however, unsatisfactory in one point which it was hoped later work might clear up. This was the exceedingly irregular distribution of the faults and fractures which could not be made to fall into any system. Neither did they seem to show any close relation to the larger structural features of the region. This difficulty is apparently to disappear as a result of the recent work. A great unconformity, partly due to land erosion and partly to underground solution, is quite adequate to explain any irregularity in the distribution of the shale patches, and, considering the weakness of the shales as compared with the limestones, it is clear that the great filled-in channels and sinks must have localized and controlled much at least of the minor and possibly some of the major deformation of the district. The boundary planes of these channels and sinks are the natural planes of readjustment, so that faulting relatively small in amount of throw, comes to assume all the appearance of major displacement. To one familiar with the methods of mine work in the Joplin district and the character of the ground, it will not be surprising that such phenomena have

[1] Iowa Geol. Surv., Vol. I., 169–179, Des Moines, 1893.

proven deceptive. The larger development of the sheet-ground in recent years has afforded the needed opportunity for correcting these false impressions.

Mr. Siebenthal has shown, I believe quite correctly, that many at least of the apparently heavy faults have only a slight throw and he has given such a reasonable explanation of the phenomena that the burden of proof is evidently upon us, if any there be remaining, who would still maintain a belief in faults of larger throw. Personally I must confess that such seem to me now to be exceedingly unlikely to be present, though they are far from impossible and it is quite true that there are differences in elevation of one hundred feet or more in identical beds of limestone within distances so short as to suggest step-faulting, at least rather than simple monoclinal folding.

In the matter of the bearing of these discoveries on the theory of the genesis of the ores I shall not at this time say much. While it is true that single faults of four to six feet are not likely to persist in depth two thousand feet or more, it is none the less probable, as it seems to me, that such zones of faulting as are present do break up and disturb the rocks sufficiently to establish a connection between the artesian waters of the Cambro-Ordovician and those of the Boone formation. Such a connection seems furthermore to be established by many independent facts of ore occurrence and association, and such a connection is all that is necessary so far as is concerned the theory of genesis put forward by myself and associates in the work of 1900.

H. F. Bain.

REVIEWS.

The Geology of South Africa. By F. H. HATCH, Ph.D., M. Inst. C. E., president of the Geological Society of South Africa, and G. S. CORSTORPHINE, B.Sc., Ph.D., consulting geologist to the Consolidated Gold Fields of South Africa. Pp. xiv + 348; Plates I. with two colored geological maps and eighty-nine figures in the text. Macmillan and Co., London, 1905. The Macmillan Company, New York, 1905.

For some years an unusual interest has attached to geological conditions in South Africa. The immense output of diamonds from an increasingly large number of mines whose character is not duplicated in any part of the world and the extraordinary gold production of the banket reefs, as well as the prevalence of conditions which have thrown new light on the problems of glaciation are in part responsible for the large share of attention which the technical and popular mind has bestowed on this region. The South African war, too, arresting as it did the rapid progress of economic development, served to emphasize the vast resources of the country.

The progress of mining exploitation has, however, been so rapid that geologic investigation has not kept pace with it and the inadequacy of published accounts of the geology has increased the natural tendency of the popular mind to look upon this country as a modern El Dorado.

The appearance of the GEOLOGY OF SOUTH AFRICA by two of the ablest of English investigators is therefore to be warmly welcomed by both geologists and technical men.

The volume comprises an introduction and six separate divisions. The introduction is divided into two parts, the first containing a full summary and discussion of all previous work by both private and official investigators. Their views are clearly and concisely stated and where later investigations have proved

to be at variance with them it is so stated and the reasons briefly given. The reader is thus furnished at the outset with an excellent historical outline.

The second portion of the introduction contains a table of the several stratigraphic horizons of the South African rocks and a brief exposition of the generalities of their distribution, geologic age and the reasons for the adoption of the various names employed. In outlining them the authors divide the country into six provinces, Southern Cape Colony, Northern Cape Colony, Orange River Colony, Natal, Rhodesia and Transvaal. For each of these geographical areas a separate table of stratigraphic horizons is given inasmuch as the subdivisions of the larger rock systems are materially different in each of them. By a carefully prepared table these various subdivisions are correlated with one another and with the corresponding European equivalents.

The larger divisions are in each case the same and may be readily grasped from the following tabular statement:

European Equivalents.	South African Rocks.
Cretaceous	Coastal System.
Rhaetic Permo-Carboniferous	Karoo System.
Age Undetermined	Cape System (Waterberg System). Potchefstroom System. Ventersdorp System. Witwatersrand System.
Archaean	Archaean System.

By a careful examination of the introduction and table of contents the reader is thus afforded a comprehensive grasp of the plan of the work and may readily turn to any portion of it which is of special interest to him.

The body of the book is divided into five parts.

Part I. deals with the pre-Karoo rocks, which, owing to the great variations in their character and their subdivisions in the different areas are treated geographically in two sections. Part II. deals with the Karoo rocks. Part III. is devoted to the post-Karoo rocks, Part IV. to volcanic rocks of doubtful stratigraph-

ical position, and Part V. to a detailed discussion of the correlation of South African strata.

The facts in each chapter are clearly stated and the discussion of the several formations is arranged with such system and care and so admirably illustrated by numerous half tones, maps and sections that even readers who are wholly unacquainted with the country may readily grasp the essential features of the geology.

Two colored geological maps, one on a scale of about seventy-nine miles to an inch, covering the whole of the southern portion of South Africa from a point about and below Johannesburg, and the other a larger scale map of the Transvaal add much to the value of the work. A generalized section of the map of South Africa would have rendered it still more serviceable.

The three chapters which are of most interest to students of economic geology are the two devoted to the Witwatersrand system and containing the discussion of the gold-bearing banket conglomerates and that entitled "The Diamond-bearing Deposits."

The Witwatersrand system is a group of rocks separated by an unconformity below from the intrusive granites and metamorphic rocks of the Archaean and by an unconformity above from the Ventersdorp system of amygdaloidal and fragmental volcanic rocks. The system consists of a lower and an upper division, the subdivisions of which may be readily understood from the following table:

Witwatersrand System.	Upper Division.	Elsburg Series.
		Kimberley Series.
		Bird Series.
		Main Reef Series.
	Lower Division.	Doornfontein Series.
		Hospital Hill Quartzites.
		Hospital Hill Slates.
		Speckled Bed.
		Red Slates.
		Ripple-marked Bed.
		Water Tower Slates.
		Orange Grove Quartzites.

These rocks form a series of steeply inclined beds which dip sharply to the south, so that one passes southward across their upturned edges from the base of the Orange River quartzite lying

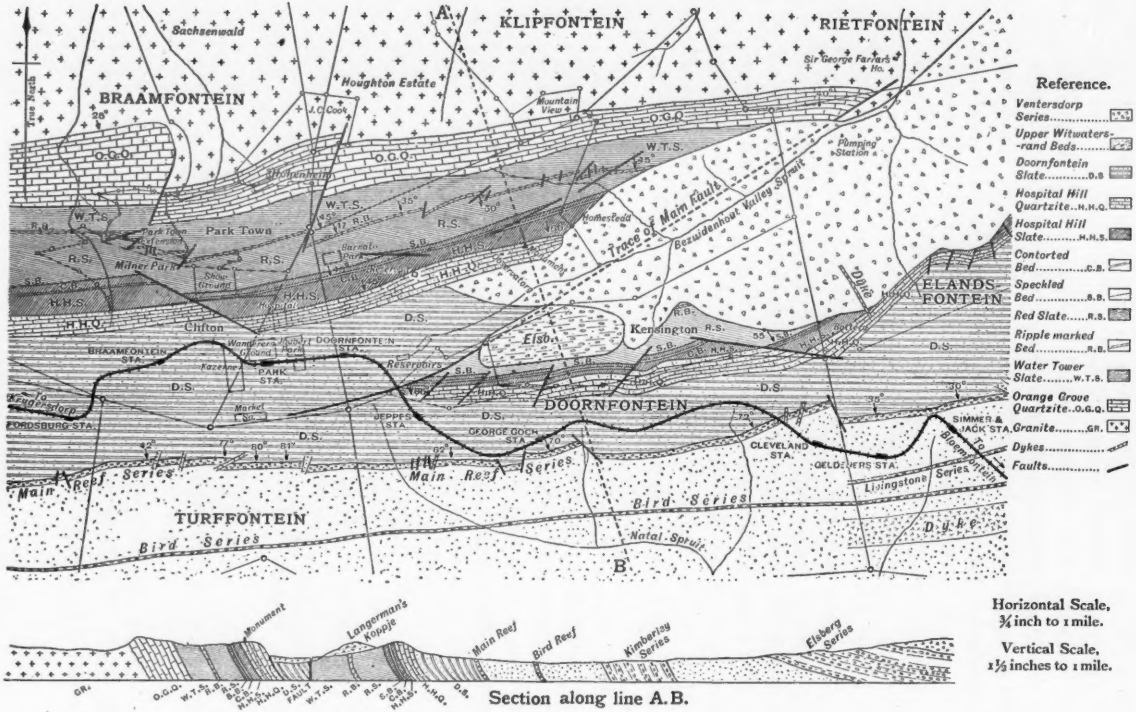


FIG. 11. — Plan and Section of the Witwatersrand Series in the vicinity of Johannesburg. — Hatch and Corstorphine.
(Reproduced by permission of the Macmillan Company.)

unconformably against the granite on the north to the Elsburg series beyond the limits of the gold-bearing territory on the south. The dip gradually decreases in a southerly direction. The rocks are complicated and the outcrops often repeated by faults. These have been carefully worked out, especially in the Main Reef series.

These relations may be readily grasped from the very excellent geological line map and accompanying section. On account of the unusual interest of this series of rocks this map and section are here reproduced by permission of the publishers.

A number of excellent analyses of the different members of the various series are given and the petrography, general character and structural relations of the rocks are most admirably presented. In the second of the two chapters mentioned, that dealing with the upper member of the Witwatersrand system and including the gold-bearing series, the various members are given in detail together with a number of careful tables of estimated thicknesses of the rocks.

The upper division of the Witwatersrand system consists of conglomerates, grits and shales, conformable throughout, the two former being present in by far greatest amount and in all cases marked by the presence of much secondary silica. The series is about 11,000 feet in total thickness.

A new departure from previous works is the separation of the Elsburg series by an unconformity from the underlying members.

The structural relation of the gold-bearing conglomerates and their petrographical character is then discussed. The extended experience of Mr. Hatch in petrographical work renders this discussion unusually valuable. He points out the secondary origin of the quartz matrix in which the pebbles are enclosed and describes in detail their physical character. The much discussed pellets of pyrite which have led some authors into the errors of the theory of contemporaneous deposition are shown clearly to be of secondary origin.

Six pages are then devoted to a discussion of the origin of the gold in the conglomerates. The three main hypotheses are successively presented and discussed. They are:

Section along line A.B.

FIG. 11. — Plan and Section of the Witwatersrand Series in the vicinity of Johannesburg. — Hatch and Corstorphine.
(Reproduced by permission of the Macmillan Company.)

1. The gold was mechanically deposited with the pebbles of the conglomerate as the result of the denudation of some preëxisting auriferous rocks. That is to say, the conglomerates represent ancient alluvial or placer deposits.

2. The gold was present in solution in the waters by which the conglomerate was laid down, and while the pebbles were accumulating as a result of mechanical action, the gold itself was being chemically precipitated.

3. The gold, with the other minerals (quartz, chalcedony, pyrites, etc.), which now form the bulk of the matrix, was introduced by percolating waters into the interstices of the partially solidified conglomerates.

The conclusion of the author is wholly in favor of the third hypothesis of subsequent infiltration of the gold. As it has been reached after much careful and exhaustive work, no reasonable doubt is left in the reader's mind as to its validity. The reasons for the author's view are briefly summarized as follows:

1. The gold is practically confined to the matrix of the conglomerate, occurring there in association with other minerals of secondary origin; the rare cases in which gold occurs in the pebbles are obviously instances of infiltration along cracks, a fact which in itself lends support to the theory.

2. It occurs in crystalline particles often surrounding or lying in close association with pyrites crystals or marcasite concretions which are of secondary origin.

3. It is uniformly distributed to a remarkable degree.

4. It is restricted to certain definite beds.

The chapter on the diamond-bearing deposits is included in that part of the work entitled "Volcanic Rocks of Doubtful Stratigraphical Position." It contains thirty pages and is profusely illustrated by full page plates of the chief diamond mines, together with a series of comparative sections of the Kimberly, De Beers, Bulfontein, Du Toits Pan and Wesselton pipes. The volcanic nature of the pipes is emphasized and the fact brought out that the circular form is not invariable, as pipes lenticular in plan and connected by means of dikes of yellow ground occur. A ground plan of the Monastery mine is given to illustrate this

feature. A petrographical description of the material filling the pipes follows the general description of the mineral fragments contained in the matrix. The diamond mines are then considered in separate groups according to their geographical distribution.

The discussion of the origin of the pipes and the diamonds which they contain is rather a brief summary and critical comparison of different views than a statement of individual opinion, although the writers incline to the belief that the pipes were produced by explosions of steam and later filled by mud-like volcanic breccia containing the fragments of all of the minerals so far found. They seem further to favor the view that the diamonds originated in the blue ground itself or the rock from which the blue ground was formed, the fragmental character of many of the gems being explained by the motion of the material within the pipes subsequent to their formation. In reading over the passages which deal with the origin of the diamond, the reader involuntarily recalls the attitude of extreme caution so strongly marked in Mr. Gardiner Williams' recent paper on the subject. While it is true that such an attitude does not so far characterize the work of the authors of this book as to lead them to the statement of an absolute negative conclusion, there seems to be some hesitation in the drawing of what appeals to the reader as a perfectly legitimate conclusion. One cannot turn from the reading of so careful a statement of facts as is contained in this chapter without a feeling of profound regret that so much painstaking scientific research has been productive of no more definite results.

In conclusion it may be said that this book presents a clearer, more comprehensive and more intelligible account of the geology of South Africa than anything which has yet appeared and such defects as it may seem to possess are due more to the inherent difficulty of the subject and the limited amount of geological investigation that has been completed in this interesting field than to any other cause.

The typography, system, style, illustration and general plan of the book leave little to be desired, while the exhaustive bib-

liography and detailed references made throughout supply a need that has never yet been met with such admirable completeness.

J. D. IRVING.

The Non-Metallic Minerals, Their Occurrence and Uses. By GEO. P. MERRILL. Pp. xi + 407. Plates I–XXXII. and twenty-eight figures in the text. John Wiley & Sons, New York, 1904.

This work, as the author states in his preface, is founded on a Guide to the Collection of Applied Geology in the National Museum, and in it his object has been to bring together "the widely separated notes and references relative to the occurrences and uses of sundry minerals of value other than as ores of metals." In discussing the various minerals he has given them a mineralogical rather than an economic grouping, *i. e.*, elements, sulphides, halides, oxides, etc., which has the disadvantage of separating minerals with similar uses, and segregating others of unlike application.

Under each mineral there is included a statement of its properties, mode of occurrence, origin and uses, in the compilation of which the author has turned to many different sources of information. The discussion of each mineral concludes with a bibliography, which might have been more serviceable had it been alphabetically arranged.

In glancing down the list of contents one cannot but be impressed by the great number of minerals which have been put to some practical use. A few of the ores of zinc, lead and mercury, which have applications in the non-metallic form without reduction might with propriety have been included, had the uses of the several products received greater emphasis.

That the book has more of the features of a systematic mineralogy than a work on economic products will appear from the fact that there are included many rare minerals, such as gadolinite, samarskite, yttrotantalite, etc., and that some of these, such as rhodochrosite, have no commercial application. While the work contains a vast amount of information, collected from all available sources, and cannot fail to serve as a useful work of reference, it is to be questioned whether its somewhat diffuse character will permit its extended use as a text-book.

H. RIES.

Records of the Geological Survey of India. Vol. XXXII., Part I., 1905. Review of the mineral production of India during the years 1898 to 1903. By T. H. HOLLAND, F.R.S., Director Geological Survey of India. Pp. 118. Plates I.–VI.

This is more than a mass of statistical tables. It is a valuable and readable account of the general progress of development of the mineral resources of India through a period of five years and of the geological conditions under which the various products occur. Three things stand out prominently in this summary: (1) The steady increase in the production of gold, petroleum and manganese ore, (2) the absence of the enterprise or of the industrial conditions that are necessary for the development of metalliferous deposits requiring smelting or other complex processes for their utilization, and (3) the fact that the gold output, $2,302,493 in 1903, far exceeds in value that of any other mineral product, over 99 per cent. of this gold coming from a single lode in the Kolar field in Mysore—a lode that averages about four feet in width and is more or less productive for a distance of a little over four miles.

In 1903 India produced 6,996,438 tons of coal, of which 94.1 per cent. was consumed at home, the balance going to Ceylon and the Straits Settlements.

It is of interest to note that saltpeter, the fourth in value of the Indian mineral products, is not a natural product at all, but is obtained by leeching from the soil around villages the salts accumulated by a population that for generations has used wood and cow dung for fuels.

F. L. RANSOME.

Geological Survey of Queensland. By B. DUNSTAN. Publication No. 196, Records No. 2, 1905. Pl. I.–V. Pp. 26.

This bulletin contains short notes on: Gold deposits near Mt. Ubi; the iron stone of Mt. Lucy; monazite; tests on Queensland coals, and mineralogical notes.

In the paper on monazite, the author describes the occurrence of monazite-bearing sands at the mouth of the Johnstone River. The mineralogical composition of one sample gave: Ilmenite, .84

per cent.; magnetite, 1.8 per cent.; zircon, 1.4 per cent.; quartz, 4.4 per cent.; monazite, 1.2 per cent.; tantalite, .90 per cent.; garnet and other silicates, 5 per cent.; moisture, 8 per cent.

Monazite, associated with wolframite, scheelite, topaz and feldspar, occurs in greisen, in the Walsh and Tinaroo mineral fields of northern Queensland, but has hitherto attracted but little attention, as it has commonly been thrown aside in the wolframite mining.

H. RIES.

The Mining and Quarry Industry of New York State. By D. H. NEWLAND. Bulletin N. Y. State Museum No. 93, Economic Geology, 1905. Pp. 69. Albany, 1905.

This report presents a summary of the mineral resources of New York State in 1904. While the mineral industry as a whole has shown a healthy growth, the increased production of iron ores has been specially marked. Of some interest is the statement that carbon dioxide is produced in commercial quantities at Saratoga Springs. This is obtained from the mineral springs; it is liquefied under pressure and sold for carbonating artificial waters.

H. RIES.

Economic Geology of the Bingham Mining District, Utah. By JOHN MASON BOUTWELL, with A Section on Areal Geology, by ARTHUR KEITH, and An Introduction on General Geology, by SAMUEL FRANKLIN EMMONS. United States Geological Survey. Professional Paper No. 38. Pp. 413 + iii. Plates I.–XLIX., with two colored maps and one plate of sections in pocket and ten figures in the text. Government Printing Office, Washington, 1905.

The State of Utah, as compared with California and Colorado, has but recently assumed a prominent position in connection with the mining industry. That the development of what are now known to be among the more extensive and valuable deposits of metalliferous ores in the west has been so much retarded is to be attributed to the continued opposition of the Mormon Church. Since the removal in the early seventies of the ban placed by it upon mining and prospecting the State has advanced by rapid strides to the position which it now holds.

With the publication of a report on the Mercur[1] Mining District, the United States Geological Survey began a careful systematic examination of the mining districts of Utah.

In the summer of 1900, under the direction of Mr. S. F. Emmons, an investigation of the ore deposits of the Bingham district was entrusted to Messrs. Keith and Boutwell. After five years of careful work the survey has been completed and the extensive report which is the subject of this review has been issued.

The volume is divided into three parts.

The first is an introduction by Mr. S. F. Emmons, in which the general scope and character of the work is roughly outlined and a brief sketch given of the broader geologic features of the Oquirrh mountains, on the eastern side of which the Bingham mining district is located. The relation of the ores to the igneous rocks is also briefly discussed.

The Oquirrh mountains are described as one of the north and south ranges geologically known as *basin ranges* which rise about five thousand feet above the comparatively level stretches of desert which lie between them. The range separates Tooele Valley on the west from the valleys of Utah and Great Salt Lake on the east. It is about thirty miles in length and very narrow and is composed structurally of two great anticlines of sedimentary rocks with an included syncline between them. The axes of the folds extend northwestward slightly athwart the general trend of the range. The principal of these great northwest anticlinal folds passes some distance to the southwest of the Bingham district which is located on its northern and eastern flank. The rocks within the district itself form a gentle auxiliary syncline parallel to the main fold. The series most highly developed is quartzite belonging to the Upper Carboniferous period.

In Part II. Mr. Keith takes up in detail the areal geology of the Bingham district. A somewhat extended discussion is first given explaining the physiographical features—a discussion

[1] Ann. Rep. 16, Pt. II., pp. 370–455, United States Geological Survey.

which, in view of the brevity of this chapter, seems unnecessarily long.

He then deals successively with the sedimentary rocks, the igneous rocks, the structure and finally the metamorphism to which the several rock types have been subjected. The reader is much aided in obtaining a clear understanding of this discussion by the colored geologic maps and sections which accompany the report.

Briefly outlined, the geology of the region is as follows:

The Bingham district comprises an area of about four miles in width by six miles in length, and includes the mountainous country on the northwest and southeast of Bingham Cañon which runs nearly due north toward the Valley of the Great Salt Lake. From the bottom of this cañon the rounded summits of the mountains rise to a height of about 9,000 feet, about 3,500 feet above the general level of the desert.

The country rocks include sediments and eruptives. The predominant rock is an extremely thick quartzite called the Bingham quartzite which covers the greater portion of the area, and extends uninterruptedly from the bottom of the cañon to the tops of the highest summits. It is of Upper Carboniferous age.

Included within this quartzite as conformable members of the stratigraphic series are nine distinct and easily separable beds or lentils of limestone, those which are higher in stratigraphic position containing relatively large amounts of calcareous and carbonaceous shale. These are separated from one another by comparatively great thicknesses of quartzite and are extremely irregular in thickness. When followed along the strike they show a remarkable lack of persistence, wedging out to a thin edge within limited distances so that the quartzites above and below come in contact with one another and the limestone frequently disappears entirely. As it is in these limestone lenses that the most extensive and valuable ore bodies occur, it may be readily seen that their irregular nature has an important bearing on the mining development.

The igneous rocks are of two kinds, intrusive masses and surface flows.

The intrusives have been forced into the sediments either in dikes or great irregular masses transgressing from one bed to another or as sheets conformable with the bedding. They consist chiefly of monzonite and monzonite porphyry.

The extrusives or surface flows are of andesite, often brecciated by the action of cooling and later flow. The northeastern portion of the area is overlaid by a sheet of this andesite which is of later date than the monzonite and has been poured out on a previously eroded and irregular surface. Over a large portion of the eastern corner of the district the andesite is obscured by the covering of unconsolidated sands and gravels which extends from the flanks of the mountains eastward into the encompassing desert.

In structure the sediments form a broad, gentle syncline which pitches sharply to the north and west, so that the quartzite and included limestone beds outcrop along the sides of the hills and dip into them at an average angle of perhaps 38°.

Both sediments and intrusives have been much affected by faults which vary in throw from a few feet to more than eight hundred feet. The prevailing trend of these faults is a little north of west, nearly at right angles to the strike of the sedimentaries.

Quartzites and limestones have been much affected by metamorphism which has rendered the quartzite exceedingly siliceous and has caused a marbleization of the limestones in some places, a silification in others and is supposed to have led also to the formation of many of the ore deposits. The silicification of the limestone is especially noticeable and is often so complete that much difficulty is experienced in differentiating the resulting rock from the quartzite. The metamorphism decreases as one proceeds outward from the intrusive masses of monazonite as also do the number and size of the ore bodies. The metamorphism and ore deposition are therefore supposed to be genetically related to the monzonite.

Mr. Keith's discussion of the geology which occupies forty-nine pages, is concise and well expressed and conveys to the reader a clear idea of the geology of the district. It contains a

number of plates illustrating the topography and geology and certain of the lithological features of the rocks. Many of these plates, which must have been expensive and troublesome to prepare, illustrate features which are essentially trivial and lend so little to the value of the text that one cannot but feel that the labor expended in their preparation might far better have been bestowed upon a few sketch sections of the geology or a columnar section of the rocks by which the reader might have been materially assisted.

Part III. is devoted to the economic geology of the district and is written by Mr. J. M. Boutwell. It comprises the body of the work, taking up 311 of the total of 413 pages. As a whole it presents the results of a remarkably careful and painstaking study —one of the most thorough that have been completed by the Survey within recent years. The book is large and elaborate, so that the introduction of general summaries has done much to increase its value to those whose time is too brief for a careful study. The omission of such summaries in certain chapters is to be somewhat regretted.

The author has divided the matter into seven chapters. Chapter I. is a detailed history of the development of the region; chapter II. is a discussion of the character of the ores; chapter III. is devoted to the geological occurrrence of the ore-deposits; chapter IV. deals with the genesis of the ores; chapter V. contains a complete description of all of the more important mines upon whose study the general statements in the earlier chapters have been based; chapter VI. contains a discussion of the placer mines; chapter VII. contains a review of the geological features which bear upon the discovery of new ore-bodies. A short addendum, containing a statement of recent developments, a list of fossils by Dr. G. H. Girty and a comprehensive index complete the volume.

A map showing the geographical distribution of the various type of ores accompanies the text and lends much to the clear understanding of the features there presented.

Chapter I. gives a detailed history of the development of the region. The author first briefly discusses the mining industry in

Utah, second, the mining industry in the Oquirrh mountains, and then passes to the mining industry in the Bingham district. The discovery and exploration which led to the real beginning of mining activity in 1870 are presented in detail and the history subsequent to that date is divided into three epochs, viz.: The epoch of lead mining, epoch of oxidized gold ore and the present epoch of copper mining. The history of the various processes of reduction and mining attendant on the passage of development from one type of ore to another are thorough and show clearly how the present successful methods have been finally attained. As the author seems thoroughly familiar with his subject this should be a valuable addition to the knowledge of the essential conditions of ore treatment. A table of production is then given, showing that between 1870 and 1900 the district produced 193,835 fine oz. of gold, 11,472,849 fine oz. of silver, 18,823 tons of lead, and 10,341,688 lbs. of copper.

A bibliography is appended to the chapter and a glance at this will serve to show how scanty is our information on the ore-deposits of Utah.

The chapter is well planned and presents briefly the essential features of the history. The tabular résumé on page 98 is a commendable feature.

Chapter II. contains 122 pages devoted to a study of the character of the ores. It is prefaced by a short general statement of the main features of interest. The mainstay of the Bingham district is the low-grade copper-iron sulphide ore which occurs in great bedded lenses in the limestones. The ore is composed of a mechanical mixture of pyrite, in part copper bearing, with chalcopyrite and black copper sulphide in a siliceous gangue. Occasionally a little galena and sphalerite are present. It contains an average copper content of about 3.3 per cent., and usually from three to four ounces of silver. A careful examination of the ore shows that the copper values are much more frequently contained in finely divided chalcopyrite mechanically mixed with pyrite than in chemical combination with the pyrite itself. This fact is of much interest as it leads the reader to suspect similar conditions in many of the now famous bodies of copper-bearing pyrite in other regions.

Next in importance to the copper-iron bodies are the argentiferous galena ores which occur in fissures. Although subordinate in importance they are extensively mined. They consist of silver-bearing galena mixed with sphalerite, tetrahedrite and pyrite in a gangue of calcite, quartz, rhodochrosite and barite. The ores contain an average of 45 per cent. lead and fifty-one ounces of silver although there is much fluctuation above and below these figures.

Historically considered Bingham has also successively produced oxidized gold ores and oxidized ores of lead, silver and copper, but the first did not prove commercially profitable and the second are exhausted.

The remaining and greater portion of the chapter is devoted to a mineralogical list of ore and gangue minerals. These include a wide variety of sulphides and alteration products which are illustrated by half-tone and colored plates. The occurrence of *pisanite,* $(Fe, Cu)SO_4 + 7H_2O$, is of interest.

Chapter III., which deals with the occurrence of the ores, is of exceptional interest and presents in a most intelligible way the geological relations of the various deposits and the causes which have operated to produce them.

The ore-bodies are grouped under four heads:

1. Fissure veins.
2. Bedded deposits.
3. Disseminated deposits.

1. The fissure veins carry argentiferous lead ores and traverse all of the rocks of the region indiscriminately. They are widest in the limestones and in the shales which contain calcareous and carbonaceous matter. The ore has apparently exercised a selective action, simply filling cavities when such lie within insoluble rocks, but spreading out in flat masses in easily replaceable beds. The quartzite is rarely if ever replaced and certain beds of limestone have been much more extensively mineralized than others. The veins are much more numerous in the vicinity of the intrusives. The ore occupies fissures formed subsequent to the intrusion of the monzonite and having a general trend in a northwest–southeast direction. Two other systems of fissures are present,

but are later than the mineralization as the ore-bodies are faulted by them. These later fissures trend northwest-southeast and northeast-southwest. Displacement along fissures is not great, being rarely more than one hundred and fifty feet. It averages from fifty to one hundred feet.

The shoots of ore in the veins where these traverse insoluble rocks are somewhat sinuous and usually exhibit a steep pitch within the material which fills the fissure. When veins lie between limestone walls, shoots are determined by the more soluble beds and pitch with the bedding in the plane of the fissure. The vein material is usually roughly banded parallel to the walls. The distribution of the bands indicates the following order of deposition from older to younger: *Sphalerite* and *tetrahedrite; pyrite* and *galena; calcite; quartz; rhodochrosite; barite.* The paragenesis is illustrated by half-tone and colored plates.

2. The bedded deposits are the ores of copper which occur as lenses in the limestone generally located well within the mass of that rock at some distance from the contact with the quartzite above and below. They constitute the chief basis of the mining industry in the Bingham district.

The ore masses all occur in the vicinity of intrusives. They are often of great size, ranging downward from a maximum thickness of two hundred feet and an equal length. None have yet been so completely mined out as to exhibit their actual size. They are roughly conformable with the bedding and despite the granular character of the ore retain the original sedimentary banding which is continuous with that of the adjoining strata; facts which are later instanced as proof of their formation by the action of replacement.

3. The disseminated ores are the auriferous copper-bearing pyrite ores. They are restricted in their occurrence to the monzonitic intrusives and occur only in the shattered areas within these eruptive rocks.

This chapter is among the best written and most clearly intelligible discussions in the book, and as a description of ore occurrence leaves little to be desired. It gives to the reader a very clear conception of the character and occurrence of the ore bodies.

It is illustrated by many admirable plates of underground ore-occurrence and by many sketches. These are all well chosen and bear directly upon the material in the text.

A most commendable feature of this chapter is the very excellent summary introduced on page 160 and the reader cannot but feel that a similar summary appended to chapter II. would have lent much to the value of the work.

Chapter V. is devoted to the genesis of the ores. It contains sixty-seven pages and is an elaborate investigation of all sources of evidence that bear upon the question. The evidence afforded by the mode of occurrrence of the ores is first considered, special emphasis being laid upon the metamorphism of the limestone and the alteration of the porphyry adjacent to the fissures. The periods and dates of mineralization are then considered, and lastly the superficial alteration which the ores have undergone since their original deposition.

Much space is devoted to the latter subject, on account of the often close dependence of high values on the relative amount of secondary alteration to which the several types of ore have been subjected.

There may be some question as to whether superficial alteration is best included in a chapter on ore genesis. There is no doubt that many of the chemical features of the ores as they at present exist are due to such alteration, but the original deposition is in itself so complete an event and so widely separated in time from the subsequent and purely accidental alteration that the wisdom of their consideration under a single heading may be open to criticism.

Inasmuch as the three types of ore occurrence have originated in different ways they are separately considered.

The great lenses of copper-iron sulphides in the limestone are regarded as contact deposits, although it is admitted that some accessions may have come through fissures at a later date. The intrusion of the monzonite masses first metamorphosed the limestone into a nearly compact marble. Waters released from this magma then permeated the altered rocks and by gradual replacement formed both the characteristic contact minerals and the ore

bodies themselves. The intergrowth of metallic sulphides and contact metamorphic minerals, the proximity to igneous masses, and the mingling of oxides and sulphides of iron, give evidence of contact origin; and the persistence of the larger and smaller structures of the original rocks in all varieties of ore afford conclusive evidence of their origin by replacement.

After the consolidation of the monzonites fissuring occurred which affected alike sedimentary and eruptive rocks. Heated aqueous solutions from the deeper, unconsolidated portions of the magma then ascended these channels, altered their walls and introduced additional metallic elements. At this time more pyritous copper sulphide may have been added to that formed earlier in the limestone in connection with contact metamorphism.

The lenses in the limestone are thus the result of two periods of mineralization, one occurring at the time of the igneous intrusion, the other after the fissuring.

The lead-ores in the fissures were deposited by the magmatic waters which were released during the second period of mineralization.

The origin of the disseminated ores which occur in shattered monzonite is considered at length and the author shows beyond doubt that they are secondary and belong wholly to the second period of mineralization.

Many plates are given to show the evidence on which the various conclusions are based and lend much to the clearness of the work.

In reading this chapter the reader cannot fail to be impressed with the almost exclusive rôle which magmatic waters have played in the origin of all of the three varieties of ore. Meteoric waters, while they have been agents of superficial alteration and secondary sulphide enrichment and have thus in large measure determined the value of the ores—have taken no part in their original deposition. The evidence advanced by the author consists wholly of observed facts and all inferences which he has drawn from them are so logical and so carefully considered as to leave no room for doubt as to the accuracy of his conclusions.

Chapter V. contains the detailed descriptions of the individual

mines which were studied in the examination of the district. They are geographically arranged and in each case systematically described. The many illustrations of geologic structure and ore-occurrence are an assistance to the reader. The collection of these individual descriptions in a separate chapter serves to remove from the more general matter a mass of necessary detail which would otherwise render the report much more difficult to comprehend.

Chapter VI. is a discussion of the placer deposits. These are now chiefly of historical interest, but have produced a total of $1,500,000. They are divided into bench, rim and creek deposits, representing successive stages in the physiographic development of the district. Most of the gold is supposed to have been derived from the croppings of ore-bearing limestone and veins, but the placers have also received accessions from deposits in the monzonite and possibly also in the quartzite.

Chapter VII. contains a discussion of the geologic features which bear upon the search for new ore-bodies and should be of much service in averting the useless expenditure of capital.

An addendum setting forth the new developments since the survey was completed and a few pages on the palaeontology by Dr. G. H. Girty complete the report.

In conclusion it may be said that this volume is one of the most comprehensive and careful surveys of a mining district that has been issued by the Survey in recent years. That a considerable time has been needed for its preparation may at first seem unfortunate, but in view of the very definite conclusions at which the author has been able to arrive and the careful accuracy of all of the statements which the work contains, it may occasion some surprise that the report has been completed so soon.

J. D. IRVING.

Black Sands of the Placer Mines of the United States. By D. T. DAY. Extract from Mineral Resources of the United States for 1904. Pp. 15. Washington, 1905.

This paper is a preliminary summary of the investigation of the black sands found in placer mines in all parts of the country

which is being made by the U. S. Geological Survey. These black sands on account of their weight collect in the riffles in placer mining. Laboratory examinations of a number of samples collected during the summer of 1905, showed that they contained a variety of minerals, including magnetite, ilmemte, hematite, pyrite, apatite, zircon, metallic copper, garnet, epidote, chromite, cinnabar, monazite, etc., the first two being probably the most abundant. Assays showed a gold content ranging from zero to 191.6 oz. per ton of concentrate, and platinum from a trace up to 128.73 oz. per ton, although the platinum content was usually under one oz. per ton. In addition, a number of concentration tests were made at a specially equipped plant at the Lewis and Clarke Exposition. Very few of the results obtained from these are as yet available.

H. RIES.

Indiana Department of Geology and Natural Resources. By W. S. BLATCHLEY, State Geologist. Twenty-ninth Annual Report, 1905. Pp. 867.

The geological papers contained in this report are: Clays and Clay Industries, W. S. BLATCHLEY; Report of the State Mine Inspector, J. EPPERSON; Report of Supervisor of Natural Gas, B. A. KINNEY; The Petroleum Industry in Indiana in 1904, W. S. BLATCHLEY.

The clay report, which is a detailed one covering the entire State, discusses the distribution of both the worked and unworked deposits, as well as their uses, and contains much valuable information. Mr. Blatchley notes that the carboniferous shales are now widely utilized for vitrified clay products, and more recently it has been found that the knobstones of Lower Carboniferous age, hitherto regarded as worthless, are also adapted to the manufacture of vitrified ware.

In the report on petroleum, M. Blatchley notes the discovery of oil in a layer of the Trenton limestone deeper than any hitherto prospected, the yield from which served to keep up the production for 1903.

H. RIES.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

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Black Sands of the Placer Mines of the United States. By D. T. DAY. Extract from Mineral Resources of the United States for 1905. Washington, 1905.

Cements, Limes and Plasters. By E. C. ECKEL. Pp. xxiv + 712. Figures 165. Tables, 254. Wiley and Sons, New York, 1905.

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Map of Cobalt-nickel-arsenic-silver Area Near Lake Temiskaming, Ontario, to accompany report of WILLETT G. MILLER in Fourteenth Report of the Bureau of Mines, 1905. With explanatory text. Ontario Bureau of Mines, 1905.

The Configuration of the Rock Floor of Greater New York. By WM. H. HOBBS. U. S. Geol. Surv. Bull. No. 270. Pp. 1–93. Plates I.–V., with six figures in the text. Govt. Printing Office, Washington, 1905.

The Theory of Copper Deposition. By A. C. LANE, State Geologist. Report of the State Geological Survey of Michigan for the year 1903. Pp. 240–250, with one figure. Robert Smith Printing Company, Lansing, 1905.

Deep Boring for Oil and Gas. Report of the State Geological Survey of Michigan for the year 1903. Pp. 270–305. Robert Smith Printing Co. Lansing, 1905.

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SCIENTIFIC NOTES AND NEWS.[1]

The recent official report of the Canadian Geological Survey which will be found listed in the bibliography of this journal on page — sets forth in some detail the work which the Geological Survey of Canada is now attempting to do. The data there stated furnish an interesting comparison with the work which is being carried on by the official survey of the United States.

During the past summer twenty-eight field parties have been at work for the Survey, including in all forty-six men. Of these, thirty-four were occupied chiefly with the study of mining districts or those regions where promise of valuable mineral deposits has seemed to render economic work of special service.

The remaining twelve men have been occupied with general geology, palaeontology and topography without which, of course, the other work of the Survey could not be profitably conducted.

It can easily be appreciated from these statistics that the force of men employed on work not of an economic character has been reduced to a minimum, and it is apparent that the main object of the geological survey has been to emphasize the importance of the mineral deposits of Canada and to further their exploitation. In a paragraph which is concerned with the general purposes of the Survey the director states that this is the chief object of the work, and several instances are cited where the more general geologic work of the department has been of service in mining operations.

The conditions in Canada are somewhat different from those which obtain in the United States, for in the former case the Survey is dealing with an unexplored and undeveloped region, while in the latter it is concerned chiefly in clarifying the geologic

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

problems for which extensive mining has already demanded an explanation.

That the Canadian Survey has been able to introduce into its geologic investigation, which must necessarily encroach slightly on the domain of the prospector, so dominant a scientific element would seem to promise well for the future clear understanding of the ore-deposits of the region and should do much to avert the useless expenditure of capital.

The death of Baron von Richtofen, which occurred in Berlin on October 7, has removed from the ranks of geologists one of the distinguished men of the century and one to whom all who are interested in the scientific side of geology owe a debt of gratitude, the full realization of which will come only with the passage of many years. Students of economic geology will especially remember Baron von Richtofen as the European geologist who was so long associated with the early exploring parties which examined the metalliferous deposits of the Sierra Nevada in 1865, and also as the man to whom modern science is indebted for much that is now known concerning geologic conditions in China.

Baron von Richtofen was born at Karlsruhe, Silesia, in 1832 and from early years was a devoted student of geology. He stands out among geologists as one of the prominent men who have combined the qualities of an explorer with those of a geologist. In the course of his studies he visited and published works on Tyrol, Hungary, East Asia, Siam, Java, Japan, the Philippines, California and China. He occupied successively during his later years the chairs of geography in the universities of Bonn, Leipzig and Berlin, holding the latter position at the time of his death. The regret which is felt at the loss to science in the death of this venerable geologist can be equaled only by the keen appreciation which is felt by all who have benefited by the many fruits of his energetic and useful life.

Messrs. Frederick E. and C. W. Wright, of the United States Geological Survey, who have been occupied during the past summer with geologic investigations for the United States Geological

Survey in the southeastern portion of Alaska, have returned from the field and are now in Washington, D. C.

Mr. S. F. Emmons, of the United States Geological Survey, has returned from Europe and is now in the West.

Mr. Otto Veach has been appointed assistant State geologist of Georgia. He is now engaged in the detailed investigation of the clay deposits of the State.

Mr. J. E. Spurr, who recently resigned his position as geologist for the United States Geological Survey, is now in Mexico. He will shortly return to Washington.

Sir Robert Bell, Director of the Geological Survey of Canada, who has been absent in the Yukon territory, Alaska, on official work, is visiting several of the mining districts of Canada in the interests of the Survey. He will return later to Ottawa.

Dr. Arthur C. Spencer, of the United States Geological Survey, who has been occupied with the scientific study of the zinc and iron deposits of the Franklin Furnace district, has returned to Washington. In the interests of this investigation Dr. Spencer recently visited many of the iron ore deposits of the eastern Appalachians, among others the iron mines of Cornwall, Pa., which, in the light of recent work on magnetite deposits, promise to present problems of unusual scientific interest. It is thought that this study may throw some light on the obscure problem of the origin of the Franklin Furnace ores.

Messrs. R. P. McConnell and F. H. Maclaren, of the Canadian Geological Survey, have concluded their field work in the Yukon territory and Alaska and returned to Ottawa.

Mr. E. M. Johnson, recently employed by Coxe Brothers & Co., in deciphering the geology of the anthracite beds in the neighborhood of Drifton, Pa., has resigned his position to accept employment with the Latrobe Steel Co. of Latrobe, Pa.

Mr. H. Foster Bain has resigned his position as geologist for the United States Geological Survey and accepted the directorship of the State Geological Survey of Illinois.

Mr. Robert T. Hill on Monday, October 9, delivered a lecture at the American Museum of Natural History in New York under the auspices of the Section of Geology and Mineralogy of the New York Academy of Sciences. The lecture dealt with the physical and economic aspects of the Republic of Mexico and was illustrated by lantern views.

An intercollegiate geological excursion was conducted by Professor T. A. Jaggar, Jr., of the Massachusetts Institute of Technology, on Saturday, October 28, 1905. The excursion was preceded by a general conference at the engineering building of the Institute on Friday, October 27. The geological features studied were the lava flows and conglomerates of Nantasket and the coastal physiography of Boston harbor.

Mr. Waldemar Lindgren, of the United States Geological Survey, who has until recently been in San Francisco, Cal., on official business, has returned to Washington.

During the coming January Mr. Baily Willis, of the United States Geological Survey and Carnegie Institution, will present a course of twelve lectures in the geological department of the University of Wisconsin on the subject of *Continental Variations, with Special Reference to North America.* Although the course is given primarily for students, it is also open to those not attending the University.

A recent circular issued by the American Institute of Mining Engineers announces the nineteenth meeting of the Institute, which will be held at Lehigh University, South Bethlehem, Pa., beginning Wednesday, February 21, 1906. The circular also states that the Iron and Steel Institute has invited the American Institute of Mining Engineers to hold a joint meeting in London, in the autumn of 1906, followed by excursions to the provinces.

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